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NOVEMBER 1959

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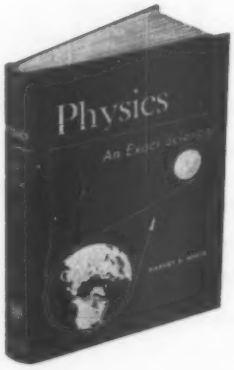

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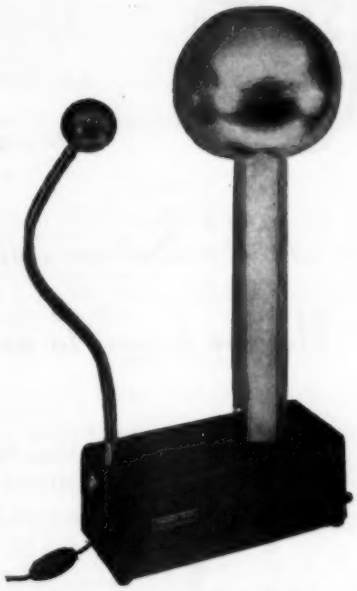

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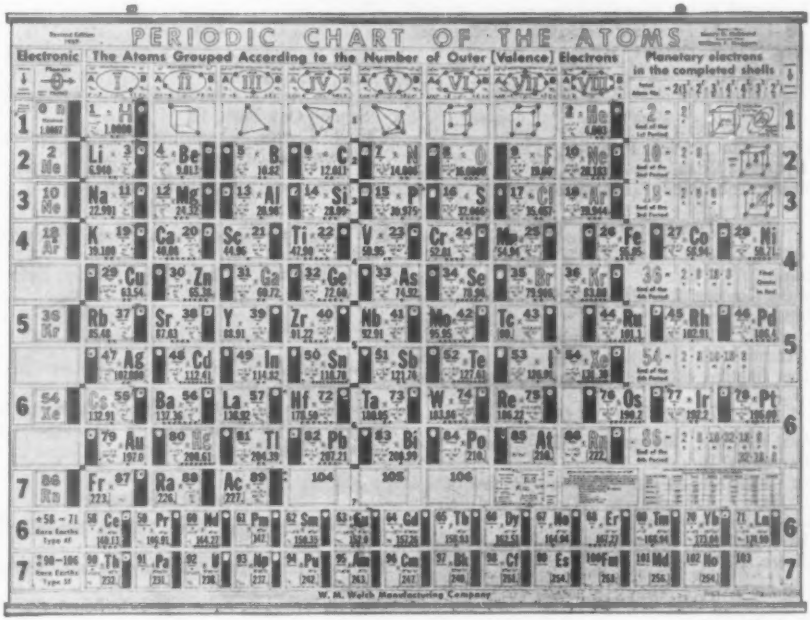
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VOL. LIX NOVEMBER, 1959 WHOLE NO. 523

Communications in Research*

Harold E. McGannon

Technical Editor, Research and Technology, United States Steel Corporation, Pittsburgh, Pennsylvania

An unsolicited personal opinion regarding the ability of engineers to communicate is, that engineers are *not* hopelessly bad communicators, especially among themselves, although their published works have gained the reputation among non-engineers for being something less than lucid, concise and well-organized. It may be that part of this reputation derives from a "language barrier," for the vocabularies of the engineering professions contain many words peculiar to the particular discipline in which any one group of engineers has been trained. Many of these words send the uninitiated to the dictionary in haste and bewilderment. Even engineers who have just completed their "basic training"—that is to say, recent graduates—may lose their way, for the language of engineering is not a "dead" language, but one that is constantly adopting or coining new words or redefining old ones. Among experienced engineers in the same discipline, however, the exchange of information is promoted rather than hindered by this precision of their technical vocabularies and their ability to convey ideas both by the written word and in purely symbolic ways that are frequently unintelligible to untrained persons.

An article entitled "Guide for Writing Reports" published by Frank Rockett in the July 25, 1958 issue of the magazine "Electronics" stated that, on the basis of recent surveys, engineers devote

* EDITOR'S NOTE: The Editor had the privilege of hearing this rather unusual paper that was presented at the English Division Meeting of the American Society for Engineering Education on June 17, 1959. Permission was obtained from the author and the ASEE for its publication. It is an unusual paper, but one which has many points of value for the scientists and mathematicians who read this *Journal*.

10% of their time to writing, and that most engineers regard only one quarter of this 10% as productive. This suggests a singular lack of enthusiasm for writing within the segments of the engineering profession that were surveyed. Under these circumstances, one might expect that the quality of written material would be less than classical. Nonetheless, the manuscripts of experienced engineers—experienced both in engineering and writing—contain no higher percentage of grammatical "clinkers" than would be expected from any comparably sized group of persons in other walks of life, *provided that they wrote as voluminously as most engineers.*

If any one undesirable trait is more apparent and more frequently met than any other in scientific and technical writings, it is poor organization of material. This may be attributable to several causes: first, the pressures on the job that prevent adequate pre-planning or outlining; second, the supposition that co-workers, supervisors, department heads, review boards, and possibly others will practically rewrite the manuscript before it is finalized anyway; third, a true distaste for composing written material, and lastly, innate inability. It is suggested that the four reasons are given in the relative order of their influence as basic causes of disorganized writing.

No facility with the language will overcome poor organization, so far as the convenience and understanding of the reader are concerned. Conversely, uncouth and ungrammatical language can impair the effectiveness of a communication—no matter how well organized—by antagonizing the intelligent reader and decreasing his receptiveness.

Because of the broad scope of the present subject it was decided to define a particular writing area that could be examined in some detail. The activities involving writing by the engineers, scientists, and technologists at United States Steel's Research Center in Monroeville were selected as a pretty broad-gauge sample for discussion. Many branches of science and engineering are represented in the research effort of the two main divisions of the Center; The Edgar C. Bain Laboratory for Fundamental Research, and the Applied Research Laboratory. Each of these divisions has its own administrative staff.

The Fundamental Research Laboratory is organized in four sections, each of which concentrates its attention on one of the following scientific fields:

Physics
Physical Chemistry
Physical Metallurgy
Metallurgical Chemistry

The Applied Research Laboratory is organized in twelve divisions, as follows:

Raw Materials Engineering
Coal, Coke and Chemicals
Process Metallurgy
Refractory and Mineral Technology
Sheet Products
Bar, Plate, and Forged Products
Chemical Metallurgy
Physics and Analytical Chemistry
Electromechanical Engineering
Steel Processing
Shops and Maintenance
Administrative Services

Over a thousand people are employed at the Research Center, and almost half of these have had formal education and intensive on-the-job training in one or more of the pertinent branches of science and engineering.

Without getting involved in a precise definition of the terms "scientist," "engineer," "technologist," and so on, the kinds of writing which form a part of the day-to-day activities of persons in these classifications can be discussed. For the present purpose, the written material may be considered as all falling into one of three very broad categories called:

1. Scientific or technical
2. Educational or interpretive
3. Administrative

The first category embraces: formal reports; formal papers for presentation to scientific and technical societies; summary reports of meetings; intramural memoranda relating to research matters; technical correspondence with customers and suppliers; technical articles for publication in trade journals, business papers, and related media; preliminary patent papers; speeches; literature surveys; book reviews; and status reports for the information of top management.

Educational or interpretive writing—the second category—includes material prepared to provide basic information to be used by others in writing: news items, advertising copy, brochures explaining research organization and activities to the layman, company-sponsored releases to newspapers and business papers describing new or improved processes and products in general terms, and generalized talks for presentation to youth groups, business-men's luncheons, and so forth. Instruction manuals also fall into this category.

Administrative writing—the third category—includes: research project authorizations, personnel appraisals, appropriation requests, budgets, cost estimates, engineering specifications.

The keeping of laboratory notebooks, wherein are recorded what might be called the "raw material" for most of the writings in Categories 1 and 2 obviously has been ignored; however, since these are essentially chronological records, they do not lend themselves to formal organization and may be considered outside the scope of the present subject. No mention has been made either of the mass of correspondence involved in the preparation and transmittal of the writings in these three categories. Other specific classes of writing that may seem to be missing from the three-way classification above are, possibly, included in one or another of the categorical items under a general class title.

Without question, the sum total of the items that have been listed represents a lot of writing. What percentage of time is spent by Research Center personnel in such activities is not readily estimated, but it is clear that an important segment of available time is spent on writing.

Except in relatively few individual cases, research today is a team effort, and the gathering of data and the reporting of results reflect this fact. While one or more persons may actually be named in the byline of the report, paper or article, it is fairly safe to assume that prewriting consultation, post-writing criticism, and editing by other experts than the author and his direct collaborators took place at various stages in the production of a given manuscript. This extension of the team-effort principle to writing is exemplified in several Divisions of the Applied Research Laboratory, where full-time editors with proper academic backgrounds review written material and provide counsel and assistance in the writing and illustration of manuscripts before those manuscripts are ready for final reproduction and distribution. This type of service is not intended to relieve the authors from the double responsibility of being accurate and of writing well. It does offer them, rather, reassurance that their writings will receive more extensive review than they themselves can afford to give. It also helps them detect weaknesses in style and offers them the opportunity to learn how to avoid these in future writing. Furthermore, aside from the advice about the mechanics of writing, the reviewers can sometimes contribute suggestions for re-emphasis, or for the addition or deletion of material that affects the understanding of the manuscript: this helps to obviate the narrowness of interest sometimes characteristic of the writing of a person who is deeply immersed in a particular phase of a problem. In other words, the reviewers can sometimes assist the writer to "see the forest in spite of the trees."

Writings in the fields of science and technology—Category 1—are based on original tests and reasoning aided by experience and the

utilization of pre-existing related data. In general, their composition follows formal lines. Their development involves presentation of observed facts or assumptions supported by theory in as logical and sequential manner as possible to support the conclusions that have been drawn from the work and that form part of the presentation. Most formal reports and papers follow a structural plan set up by the organization supporting the research or established by the journal or other publication in which they are to appear. There is little opportunity and hardly much justification for attempts to "dress up" such writing by resorting to flowery or grandiose phraseology. The nature of the audience admits of the use of technical terms that would be unacceptable in other classes of work. Good organization of the data and the simplest possible mode of expression, with due regard for ordinary rules of grammar, will suffice. The prime intent is to communicate new information or a revaluation of previously developed data on a specific subject. It may be that some background information must be included to explain the reasons for the study, or that some expansion in the form of a discussion is required, the latter to suggest some of the less obvious applications of the results. In any case, writing of this type is generally characterized by restraint on the part of the author. Recognizing the fact that his professional reputation is involved, he is usually careful to qualify each statement and is especially intent upon avoiding extravagant conclusions. Given sufficient time and cooperation, most engineers and scientists will produce a very acceptable piece of such formal writing provided: (1) that they are sufficiently experienced in their field to properly analyze and discuss their findings; and (2) that they realize the importance of writing well.

In the second category—the field of educational or interpretive writing based on scientific fact—much of the work produced will be semiformal in character, or even colloquial, depending upon the audience. Here the writer is concerned with areas of broader scope than in the case of more formal writing. He must present information using more common words than would be employed in formal writing, and include explanatory detail that requires considerable judgment in its selection. Simpler modes of expression help to hold reader interest. In the "translation," accuracy of meaning must be preserved.

When writing semiformal material—such as a metallurgist might prepare to explain a technical problem to a group of steel salesmen—he must write at a level that presupposes among his audience at least general knowledge of the subject. Steel salesmen, for example, might reasonably be expected to possess knowledge of the compositions, properties and common uses of steel. However, the metallurgist would

have to recognize the unfamiliarity of his readers or listeners with the details of laboratory techniques or even practical steelmaking, and choose his mode of expression accordingly.

In the colloquial field, the scientist's or engineer's problems are multiplied. Beside having to hurdle the "language barrier," he must inject ideas that will spark the interest of his audience, stir its imagination and hold its interest—all this without swerving too far from strict accuracy and without giving the impression of being patronizing. All too few persons, trained in the sciences, have the ability to write in this vein. In passing, it might be said that the average technically trained person has less difficulty in preserving accuracy when interpreting scientific facts in a popular vein than does a nonscientific person in attempting to explain a scientific fact in the same popular vein. This state of affairs is simply explained: it is impossible to explain anything to anyone unless you understand it yourself. This aside may help to account for some of the nine-day scientific wonders that appear in the daily press and periodicals, which, upon close examination by an informed individual, turn out to be commonplaces described in huckster terms: the central idea may be a new fact, but the glowing inferences that are drawn are purely speculative. This is another example where knowledge of the subject is a necessary adjunct to writing ability—at any level—if true communication of fact is to be effected.

In regard to the third category—administrative writing that must be performed by scientific and technical personnel—some of the staggering load that would otherwise be imposed has been minimized by the use of printed forms. In many of these, the only opportunity for composition is in the column headed "Remarks." Where original composition is unavoidable, and a letter must be written without such mechanical aids, many companies have adopted streamlined memoranda-type communications that avoid the earlier ponderous style involving a formal opening and close. This is completely adequate for internal correspondence. The semiformal and colloquial forms of writing employed promote promptness, clarity and brevity.

There are, fortunately many heartening signs of a growing awareness of the need for better training in the fundamentals of good technical writing and the application of these fundamentals to practical communication. Employers, educators, technical societies, and groups like the Society of Technical Writers and Editors, are working hard and cooperatively in several areas. First, a concentrated effort is being made to set up some sort of standards by which the problem can be accurately stated and then examined for practical solution. Second, many institutions of learning have expanded their curricula

to provide improved instruction in the fundamentals of technical writing.

Incidentally, no one has yet succeeded in defining the term: "technical writing." Everyone recognizes that there is a distinct difference in the style, organization, and language in a novel as compared with a training manual or a technical report. No one, however, has satisfactorily succeeded in separating and classifying the elements that distinguish one type of writing from another. The problem is clouded by the fact that the same information usually can be transmitted in any one of several styles, at any desired language level, with emphasis shifted from one part of the data or conclusions to another.

Some practiced writers can, from a single source of data, turn out a creditable series of separate stories or reports, aimed at audiences of widely different backgrounds and interests. A neophyte, using the same data, may have difficulty writing a suitable story or report for a single audience.

Both individuals may have equal ability to express themselves in writing on a single theme, but the practiced writer—largely through trial and error—has learned how to arrange his thoughts, select his data, and make his points reach any particular audience.

It has been said that "we learn to write well by writing." To this might be added the remark of a famous publisher to the effect that "there is no good writing—just good rewriting." This latter observation recognizes the importance of constructive criticism and conscientious editing in the production of good writing.

Undoubtedly, experience is as important to the writer as it is to the research scientist, the medical doctor, the surgeon, the lawyer, or any other professional person. Our engineers, scientists, doctors and lawyers are taught on the basis of the massed experiences of the best minds in each profession. They leave their colleges and universities armed with what might be called this "predigested" knowledge based on experience. Effective methods of communication have been found for imparting this sort of knowledge with considerable success.

Hopefully, continuing study of the communications problem will result eventually in discovering how the experiences of good technical writers can be passed on to beginners as effectively as can be the principles of a science. This is not to imply that writing is to be made an exact science. However, it may be necessary to specialize, to train technical writers without a comprehensive background of how to turn out artistic prose or poetry. Such a program would not be intended to produce scholarly writers. It would consist of highly formalized techniques aimed solely at training writers to communicate effectively in scientific and technical fields. Such formalism might limit the writer

by preventing him from at first indulging in the verbal flights of fancy and the use of picturesque expressions that are the "building blocks" of the novelist and the poet. However, if trained to write well in the one area and in one style, he would have a fundamental knowledge of the principles of good composition that would enable him to concentrate on the more artistic types of writing and gain proficiency in them if he so desired.

Perhaps this extension of the principle of specialization is open to criticism. However, if it is possible—with a mimimum expenditure of time—to train engineers and scientists to communicate well in only one field—their own—a good deal will have been gained. If the same principles can be extended to train others as specialists to do the communicating for the engineer and scientist or to lucidly interpret scientific work for a variety of audiences—much more will have been gained. When that happy day arrives, the bleary-eyed editor may no longer have to shudder as he blue pencils a sentence like: "Having eaten our lunch, the bus continued the tour of the steelworks."

SURPRISING FACTS ABOUT UPPER AIR DISCLOSED BY SATELLITES

At altitudes of 50 miles tropical and polar climates appear to be interchanged. Information derived by observing the behavior of artificial satellites indicates that the upper atmosphere circling the poles is hundreds and sometimes thousands of degrees hotter than that above the equator.

Satellites circling the earth encounter particles, atoms and molecules of gas as well as atomic fragments in the upper air, and gradually lose energy to them. In consequence, satellites spiral closer and closer to the earth and eventually enter the dense atmosphere where they burn up. If the density of the atmosphere varied uniformly with altitude and was at all times constant, then satellites should return to earth in a uniform spiral. Instead, irregularities are observed in their path which indicates that the density of the atmosphere varies, not only with latitude as might be expected but from day to day and season to season. A group of huge sunspots, turned toward the earth briefly during each revolution, hurls electrified particles into the upper air. Some of the particles are trapped by the two great belts of electrified particles which surround the earth and others are almost trapped. This additional solar debris acts as an abnormal brake on a satellite."

The outer belt of trapped matter bends down over an area encircling the North and South poles as "horns" which reach into the upper atmosphere. Here, the trapped particles collide with and heat the air to temperatures as high as 2,500 degrees, more than twice that above the tropics. It appears that unusually violent solar outbursts are capable of sending temperatures even higher and the extreme agitation of the atmosphere in the horns gives rise to the auroral lights. Particles are trapped by the belts most effectively when the axis of the earth's magnetic field makes a right angle with a line drawn from the sun. This occurs twice each year at the time of the vernal and autumnal equinoxes when auroras are seen in greatest profusion.

Discipline in Numbers—A Way to Stimulate the Gifted

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It is extremely satisfying when we find things out by ourselves. We do not have to be grown up with years of education, training, and experience to start searching for ideas. The result of our search does not have to be new or original. The most important result is finding out our abilities.

We take time to discuss some ideas from the work of Ibn Bannaa (1258–1339), a mathematician from Morocco. It is interesting and also encouraging for a young person around the age of nine or ten to know that Ibn Bannaa found the following result when he was a young boy about nine or ten. He did not need anything but a knowledge of multiplication. First he discovered

$$\begin{aligned}
1\times 1 &= 1,\\
11\times 11 &= 121,\\
111\times 111 &= 12321,\\
1111\times 1111 &= 1234321,\\
11111\times 11111 &= 123454321,\\
111111\times 111111 &= 12345654321,\\
1111111\times 1111111 &= 1234567654321,\\
11111111\times 11111111 &= 123456787654321,\\
111111111\times 111111111 &= 12345678987654321.
\end{aligned}$$

He stopped here because he knew arithmetic only to the base ten. If we learn arithmetic in a base more than ten, we can continue this process.

Ibn Bannaa's idea can be modified for the case in which the number of digits is more than nine. We shall do this with an example and leave the explanation of it to the reader.

Example:

$$\begin{aligned}
111111111111\times 111111111111 &= 123456789\\
&\quad\ 10\\
&\quad\ 11\\
&\quad\ 12\\
&\quad\ 11\\
&\quad\ 10987654321\\
&\overline{\qquad\qquad\qquad\qquad\qquad\qquad}\\
&12345679012320987654321.
\end{aligned}$$

A number with all digits equal to 9 can be multiplied by itself using another trick of Ibn Bannaa, e.g.,

$$99999 \times 99999 = 9999800001.$$

Can you explain how this is done? Note that $9 \times 9 = 81$. Then look at the answer above and you will see the rule.

Here is another interesting idea of Ibn Bannaa. We shall give an example for Bannaa's rule:

$$999 \times 666 = 665334.$$

Note that both numbers have the same number of digits and one of them consists only of 9's. As a hint we mention that

$$9 \times 6 = 54,$$

and

$$9 - 6 = 3.$$

Can you figure out the rule? Let us have another example:

$$9999 \times 7777 = 77762223.$$

Again

$$9 \times 7 = 63,$$

and

$$9 - 7 = 2.$$

Ibn Bannaa has many other ideas which are somewhat deeper in quality. His most interesting book, *Shortcuts in the Science of Arithmetic*, has been translated from Arabic into French by Aristide Marre.

Having seen some discoveries of one young mathematician you can start searching for the pure enjoyment of it.

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UNDERSEA CABLE WILL AID AIR TRAFFIC

A new transatlantic cable, designed to improve communications for air traffic control across the North Atlantic, will be laid from Newfoundland to Scotland, via Greenland and Iceland, the International Civil Aviation Organization reported. Its use will help ease many radio communications problems that have caused passenger service delays and additional costs to airlines during transatlantic flights. Existing high-frequency radio teletype circuits in the area are subject to frequent radio blackouts caused by the aurora borealis.

Art and the Biological Sciences

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An unchallenged opinion held by teachers of the biological sciences for many years was that "the best eye for a naturalist is the point of a pencil."

Today, a trend away from student-made drawings as a basis of laboratory observations, is evidenced by a study of current laboratory guides which are provided for students in many schools. That the issue has been controversial for more than two decades can be seen by referring to books on methods of teaching biology which have been published during that period.

The purpose of this paper is to reveal the ways in which art and biology have been related in the past, to show the place of the artist in this field today, and to determine whether we are clinging to a tradition which has outlived its usefulness when we continue to utilize student drawing as a teaching method in the modern laboratory.

One can really begin at the beginning in this subject, since the earliest records in the form of pictorial representations were made by man about fifty thousand years ago.[1] Modern man has inherited this amazing legacy of art from his primitive ancestors, in paintings and sculpture found in caves and caverns in various parts of the world. Some of the most awe-inspiring works have been found in caves in the region of Lascaux in southern France. There, as in most of the art of primitive man, beautifully depicted animals are the main subjects. The representations of animal forms indicate such accurate observations of limb-motion and anatomical features that surely no one could object to the naming of these primitive artists as the first naturalists. Modern archeologists tell us that these cave paintings were associated with various religious rites and were created for that purpose.[2] It seems logical, however, that at first, some members of that primitive group felt the creative urge to record their observations of nature pictorially, and these were later woven into the pattern of their early religion. Perhaps one cannot attribute much scientific insight to these early observations of nature, but they are visible proof that man has created pictorial representations of natural objects long before written history.

As man advanced in his development toward what we egotistically term a "civilized state" because it more closely approximates that

[1] William A. Locy, *The Story of Biology* (New York, Garden City Publishing Company, Inc., 1925), p. 14.
[2] Georges Bataille, *Lascaux*, trans. Austryn Wainhouse (Switzerland, Skira, n.d.) p. 129.

in which we exist, he found that his observations of nature could be an advantage to his well-being. Studying animals and their habits made it possible for him to kill and to avoid being killed. Helping nature along by watering an edible plant during periods of drought was the beginning of farming. There are evidences of this evolution in man's growth in the campsites and tools which have been found as well as in carvings and paintings similar to those already mentioned.

To many of us, the name of Aristotle suggests antiquity, but in his work in the biological sciences he refers to "the ancients"[3] whose treatises he studied before preparing his own. We know that Aristotle made drawings of observations because, in his writings, he frequently refers to sketches, saying "for the disposition of these parts I must refer to my anatomical diagrams."[4] These drawings, unfortunately, have been lost, but Aristotle must have felt it just as impossible to describe an organism, without the use of drawing, as it would be to describe a circular staircase with one's hands tied behind his back.

Many ancient manuscripts by various authors have been preserved, complete with their illustrations of both plants and animals. The beauty of these drawings and their accuracy indicate original observation with attention given to detail. During the period called the Dark Ages, however, illustrations were copied from manuscript to manuscript for hundreds of years before they finally made their debut as woodcuts in printed books. These products of years of copying and recopying often resulted in an inferior illustration,[5] a process rather like the game called "Telephone," in which a phrase is whispered to the first person in a line, who in turn whispers the message to his neighbor and so on down the line. Usually the statement which the last person hears is very different from the original.

The introduction of pictures into printed books of science was an important step in making the subject more appealing and more understandable to greater numbers of people. In early herbals, which were the first printed books which contained illustrations, it is interesting to note that if an herb was credited with the powers of healing the bite or sting of an animal, that animal is shown with the plant in the same woodcut; for example, the plantain is accompanied by a serpent and a scorpion.[6] This device is thought to have been for the information of those who could not read as it becomes less frequent in later herbals.

The preparation of woodcuts directly from nature took place during the Renaissance, for it was then, in many fields of learning, that

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[3] Locy, *Story of Biology*, p. 27.
[4] *Ibid.*
[5] Agnes Arber, *Herbals, Their Origin and Evolution* (Cambridge, University Press, 1938), p. 186.
[6] *Ibid.*, p. 15, Fig. 1.

man began again to think for himself instead of resorting to echoing the thoughts of others. Woodcuts prepared in this manner, from nature, directed attention to details and promoted observation, a factor which was of extreme importance at a time when the very right to independent observation was struggling to exist.

Improvement in the early illustrations in printed material was also brought about in the sixteenth century, when some of the fine artists of the day became interested in drawing for wood-engraving. Two of these were Albrecht Dürer (1471–1528) and Leonardo da Vinci (1452–1519).[7]

Leonardo da Vinci should be mentioned also as a pioneer in the study of anatomy, although his influence in this field was indirect. Because his work was in the form of rough notes and not published as a whole until the twentieth century, its true worth was not recognized in his day. However, the influence he exerted upon other painters and sculptors of the Renaissance, through his insistence upon the study of anatomy, most certainly gave encouragement to direct observation, and consequently upon the development of the biological sciences.

Da Vinci's study of anatomy was much more than a tool to increase his skill as an artist. He is known to have dissected thirty human bodies, both male and female, and his detailed drawings of the heart and the vascular system are proof that his interest in structure exceeded that of an artist.[8] His observations were recorded as sketches, and based upon them were his written speculations on the physiology of the structures. His views on the value of drawing is expressed in these notes which were written at the side of a drawing of the heart:

> With what words, O writer, can you with a like perfection describe the whole arrangement of that of which the design is here? . . . I counsel you not to cumber yourself with words unless you are speaking to the blind . . . Do not busy yourself in making enter by the ears things which have to do with the eyes[9]. . . .

If Leonardo da Vinci's anatomical drawing had been given to the world in his day, he would probably be recognized today as the restorer of personal observation in the field of anatomy before Andreas Vesalius. Figuratively speaking, perhaps Vesalius could have advanced to even greater heights if he had been able to stand upon the shoulders of da Vinci.

Although the work of da Vinci was prepared in 1510, some thirty years before that of Andreas Vesalius, the latter is considered to be the Father of Anatomy. Where da Vinci's anatomical work did not

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[7] Ibid. Plate xx, xxi.

[8] Elmer Belt, *Leonardo the Anatomist* (Lawrence, University of Kansas Press, 1955).

[9] *The Notebooks of Leonardo da Vinci*, comp., trans. Edward MacCurdy (New York, Reynal and Hitchcock, 1939) p. 43.

receive the attention of his scientifically minded contemporaries,[10] Vesalius made a profound impression upon his countrymen. Because many of his observations were in opposition to those of Galen, he aroused the antagonism of many individuals, even among the learned. Nevertheless, Vesalius felt that it was imperative that he record his anatomical observations in print. He recognized the value of illustrations and enlisted the help of eminent artists to create finished drawings from his original preparations. Vesalius supervised the preparation of the drawings as well as of the book's printing. One of these hired artists was John de Calcar, a pupil of Titian's, who is not remembered by many for his artistic achievements, but whose work was of such excellence that it was frequently attributed to his master.[11]

Fortunately for posterity, it seems that throughout the ages many biologists felt the need to record their observations pictorially. Many could be mentioned, but it will suffice to name only a few. Anton van Leeuwenhoek (1632–1723), for example, was a Dutch spectacle maker who laid the foundations for Protozoology. He was without scientific training and did not set out to accomplish this end, but through his indefatigable curiosity in examining every imaginable material through the microscopes he constructed, and by leaving charming sketches of the "animalcula" he observed, new vistas were opened to those who followed him. In the field of comparative anatomy, Georges Cuvier (1769–1832) left writings as well as excellent drawings of the animals he studied.

That each biologist who left drawings possessed insight to know that his work would be studied by future generations is doubtful. It is not inconceivable that drawing was the natural reaction of the analytical mind of the scientist to force his attention upon detail and to sharpen his observation.

Perhaps the reader has come to the conclusion that relying upon drawing was fine in the days when making a pictorial representation of a specimen by hand was the only means of capturing its likeness for posterity. One may question the necessity for the artist in the biological sciences today, when we have at our command marvelous machines to photograph a likeness without error. Consider, however, that this very fact of recording exactly what is there can be a disadvantage. The artist can do more than that. To aid the student, he can delete those structures which are superfluous in the study of the particular point at hand, or he can simplify, emphasize or minimize certain features to give the student better understanding. When study of such a diagram is followed by observation of the specimen itself,

[10] This lack of recognition was probably because da Vinci was regarded primarily as an artist, and his scientific works were not published.

[11] Locy, *Story of Biology*, p. 168.

the latter will be more clearly understood. In even the most up-to-date biology texts, one finds that some photographs are used, but most of the illustrations consist of diagrammatic drawings.

More pertinent, however, than any of the aspects of this problem mentioned heretofore, is the question of the place of student-made drawings in the twentieth century biological laboratory. Even though we accept the fact that the scientific artist still has a role to play in the preparation of meaningful texts, charts, and models, should we not question the value of the traditional laboratory drawing as required of each student? This has been a controversial subject for a number of years and in some schools drawing has now been minimized or eliminated. Until recently, this trend was confined to high schools, but some colleges and universities are now following suit. One can find evidence of the trend in a perusal of laboratory manuals which are provided for students' use in many institutions. These manuals often provide most of the drawings already made, for the student either to complete after looking at an actual specimen, or to merely label.

Reasons for this trend might be found in the increased enrollments in most institutions of learning. Large classes make the checking of laboratory drawings a time-consuming chore, and the instructor often feels that he does not have time to correct errors in observation as they occur.

The books concerned with the methods of teaching biology, which were available to the writer, were divided in opinion. Those which advocated student drawing seemed agreed that drawing compels precise observation of details, and some referred to the disciplinary value of such requirements.

Many traditionalists seem to echo the opinions of Thomas Huxley (1825–1895), although perhaps to a lesser degree.

> I should make it absolutely necessary for everybody, for a longer or shorter period, to learn to draw. Now, you may say, there are some people who cannot draw, however much they may be taught. I deny that in toto because I never yet met anybody who could not learn to write. Writing is a form of drawing; therefore if you give the same attention and trouble to drawing as you do to writing, depend upon it, there is nobody who cannot be made to draw, more or less well. . . . I do not say for one moment you would make an artistic draughtsman . . . but you can teach simple drawing, and you will find it an implement of learning of extreme value. I do not think its value can be exaggerated, because it gives you the means of training the young in attention and accuracy, which are the two things in which all mankind are more deficient than in any other mental quality whatever. . . . You cannot begin this habit too early, and I consider there is nothing of so great a value as the habit of drawing, to secure these two desirable ends.
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> Thomas Henry Huxley, in "Science and Art in Education"; from *Science and Education, Essays.*[13]

[13] As quoted by: Justus F. Mueller, *A Manual of Drawing for Science Students* (New York, Farrar and Rinehart, 1935) Preface.

Criticisms of the traditional drawing-requiring method are often aimed at the type of drawing which is required in many classes. Critics point out that the execution of the drawing often becomes the main objective for the student, and the desired learning process does not result. The kind of drawing meant is one in which the student tries to make his drawing as much like the specimen as possible. Much time is consumed in the drawing process, the artistic student produces the best drawing, but this does not necessarily indicate accurate understanding of the material.[13]

Any attempt to carry out an experiment in laboratory classes to determine the effectiveness of student-made drawings as a teaching aid would be difficult, with any degree of accuracy, since the classes being compared would have to be of equal inherent abilities at the outset. To some extent, then, the solution to this problem must be reached through rationalization.

Perhaps the reader will agree that an individual can acquire knowledge in a variety of ways. Some learn best by reading, some by listening to a lecture; but how many times have we read or listened without comprehending, or what's more, have thought of other things while either process was taking place? The writer has often marvelled at the workings of her mind when she has read a story aloud to her children while her mind was nimbly functioning in planning the menu for dinner. Should not the teacher consider these peculiarities of the mind and present a topic in many ways, in an attempt to include the various types of sensory perceptions which result in learning? Although we can look and do not see, and listen, yet not hear, it is surely quite difficult to create a drawn image of an object without some learning resulting.

The teacher of biological sciences must keep in mind that not all of his students will be motivated by scientific curiosity. For many, this subject will be just another required course. From that standpoint, required drawings can be considered disciplinary. Their execution, if the above premise is true, will bring about at least some desired learning, in spite of the student's probable lack of interest. In a class consisting only of students possessing scientific curiosity, such as biology majors, pre-medicine students, etc., the teacher could probably turn them loose with the materials to be studied, without requiring sketches, and be fairly certain that learning would result. It is said, in fact, that this was the method employed by Louis Agassiz.[14] Under such conditions one might note that these students who desire knowledge, who have an innate interest in the subject, would record their observations pictorially, without prompting.

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[13] Amer M. Ballew, "Anaysis of Biological Drawings," School Science and Mathematics (Vol. XXX, March, 1930), pp. 490–497.

[14] Alfred C. Kinsey, *Methods in Biology* (Chicago, J. B. Lippincott Company, 1937) p. 120.

Since the type of drawing required has been a point of criticism, we must consider the nature of the drawing if it is to be effective. If the drawing is to fulfill the purpose of sharpening observation, it should be an analytical representation rather than an artistic, merely pictorial one. By an analytical drawing is meant one in which the student shows, in diagrammatic form, the relative positions of structures in the studied specimen. The drawing itself is simple; a maximum amount of time being spent in analyzing relationships of structures.[15] This type of drawing would show the instructor at a glance whether the student was correct in his observations, it would not place a premium on artistic ability, and would help to develop analytical thinking, which should certainly be an aim of all science teaching.

A writer in a publication of *School Science and Mathematics* has this to say concerning the function of drawing in the biology laboratory:

> But we have in mind a further and more important aim, namely, to develop the student's power of analytical thinking, for which purpose no other single medium is as effective as is drawing. By analytical thinking we mean here the ability to discriminate between essentials, between what is relevant and what is irrelevant to a question; in other words, the ability "to see the point." Only so far as drawing conforms to these principles will it have any educational value.[16]

If one concludes then, that drawing is still an effective teaching method, and should not be eliminated, what can be done about the physical problem created by large classes in which it is difficult for the teacher to check drawings and correct errors as they occur? The writer would suggest a modification of the "Monitorial System." Each class usually has a few students who work rapidly, accurately, and who comprehend well. Rather than eliminate laboratory drawings in large classes, would it not be possible for the teacher to first check the work of these chosen "monitors"? The monitors would then, in turn, examine the drawings of fellow students, referring to the instructor those whose work indicated incorrect observations had been made. If each monitor were asked to check only a few students' work, and if he were given no further responsibilities, perhaps the weaknesses of the ill-reputed "Monitorial System" would be avoided.[17]

In conclusion, the writer feels, that since drawing has been an important tool for naturalists in the past, since its use can still, in many ways, surpass the camera as a visual teaching aid, and its correct use by the student will result in analytical thought, student drawing should not be eliminated from the modern laboratory.

The writer adds her voice to the many others who have insisted that "the best eye for a naturalist is the point of a pencil."

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[15] Ballew, "Analysis," School Science and Mathematics XXX, 490–497.

[16] A. M. Johnson, "Drawing and its Function in the General Botany Course," School Science and Mathematics (Vol. XXX", October, 1933) p. 856.

[17] Paul Monroe, *A Cyclopedia of Education* (New York, The Macmillan Co., 1914), pp. 296–299.

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ANCIENT POLLEN GRAINS DATE PREHISTORIC GROUND SLOTH

The menu of a giant, bear-like creature that roamed the western United States is helping scientists fill in some blank spaces in the history of man and other animals. Pollen grains which passed relatively unchanged through the digestive tract of the prehistoric ground sloth have given two University of Arizona researchers important information on the dates when the animal lived. By using the carbon-14 carbon dioxide gas counting method, it has been determined that the sloth lived in Rampart Cave, Grand Canyon, between 10,000 and 35,000 years ago.

Analysis of the pollen grains also indicated that 12,000 years ago the ground sloth was eating pine, juniper and sage brush—plants now found at higher altitudes. The climate was cooler and more moist then than it is now. However, 35,500 years ago and 10,000 years ago, when the sloth disappeared, the climate was hot and dry as it is today.

Blackboard Stencils

(Effective and Inexpensive Visual Aids)

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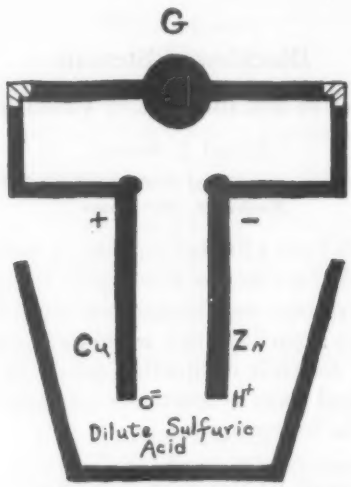
Since most schools have a limited amount of money allotted for the purchase of essential and effective visual aids, the science teacher can provide durable, accurate, and inexpensive ones by using specially designed blackboard stencils which he himself can improvise. The materials necessary for their completion are easily obtained and the stencils so improvised have a multitude of good features. Among these features are the following:

1. Accurate and correct drawings can be produced;
2. Errors in diagrammatic labeling can be reduced to a minimum;
3. They are time saving in the classroom;
4. They can be used repeatedly in various courses or over a long period of time;
5. They can be constructed with inexpensive and used materials;
6. They can be transported easily within the same classroom or between different classrooms;
7. They can be stored easily and require a relatively small amount of space;
8. They can be seen clearly by students sitting anywhere in a regular classroom;
9. They can be constructed according to the size of the individual class or the specifications of the individual teacher.

By using these improvised blackboard stencils, the teacher can select and prepare those diagrams that are pertinent to the topics that are discussed in his particular class as well as those that will meet the needs and requirements of his other courses. The only obstacle which the teacher will encounter in their preparation is the expenditure of a little time in preparing the original stencil.

Listed below is the procedure used by the writer to improvise blackboard stencils as effective and inexpensive visual aids in the science classroom.

1. Select the desired diagram that is to be used to illustrate a particular concept, principle, or fact;
2. Sketch the diagram, as large as desired, on a piece of white paper, pasteboard, or back of a used carbon stencil;
3. Cut-out the form of the diagram (approximately $\frac{1}{4}''$ along the sketched lines) with a razor blade, scissors, or sharp instrument;
4. Grind several pieces of white blackboard chalk to a powder and place it in a container which is large enough to hold a felt blackboard eraser;
5. Moisten a piece of cloth and evenly spread water over the surface of the blackboard that is to be used; (the time needed for the water to evaporate will depend upon the amount which was used to moisten the blackboard)
6. Place the completed stencil over the moistened blackboard. Tap a chalked eraser over the form of the stencil and remove it from the blackboard. The resulting diagram should be complete and well imprinted on the blackboard.



Blackboard Stencil of a Voltaic Cell

The following is an another illustration of the stencil method used by the writer to make concepts and principles clear and meaningful in the science classroom.

In the study of matter and its three states, the molecular arrangement of gases, liquids, and solids were illustrated with blackboard stencils. The stencils illustrated the following characteristics of matter:

1. The relative number of molecules in a given sample of a gas, liquid, and solid;
2. The relative arrangement of molecules in a given sample of a gas, liquid, and solid, and
3. The relative distance between molecules.

The original stencils were constructed with the following inexpensive materials:

1. A silver dollar for the form of the molecules;
2. The backs from three (3) used mimeograph stencils;
3. A razor blade

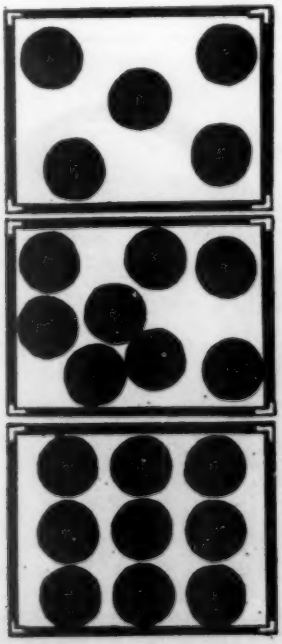
To represent the arrangement of molecules in a gas, five discs spaced irregularly on the stencil were cut out. For the diagram of the molecular structure of liquids, discs on another stencil were spaced closer together and in no particular order or arrangement. The stencil depicting the molecular structure for solids consisted of three rows and three columns of discs equally spaced and close together. When completed, the diagrams were stencilled on the chalkboard. The re-

sulting diagrams were previewed and corrections and other adaptations made on the original stencil.

Before class, the three diagrams were stencilled on the blackboard. When class resumed, such questions as the following were asked of the students:

1. What diagram, would you say, corresponds to the definition of a gas, a liquid, a solid?
2. How do the diagrams differ in characteristics regarding:
   a. number of molecules?
   b. distance between molecules?
   c. arrangement of molecules?
3. Upon which of the characteristics above would you base your conclusions regarding:
   a. gases?
   b. liquids?
   c. solids?
4. Could you formulate your own definition with the information you have obtained from the diagrams on the blackboard? Do so!

The worthiness of using blackboard stencils as described above was evidenced by the writer in the periodic evaluation of his students. The same diagrams were used in the regular weekly quiz, with the order of their appearance changed. To further substantiate their effectiveness, the diagrams again appeared on the final evaluation test of



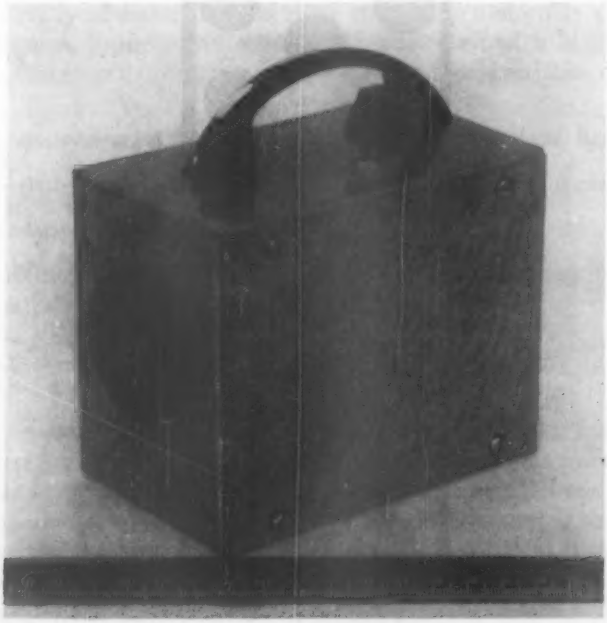
Molecular arrangement of gases, liquids and solids.

the students, however this time the order of their appearance was different from both that used in the chalkboard illustration and the weekly quiz.

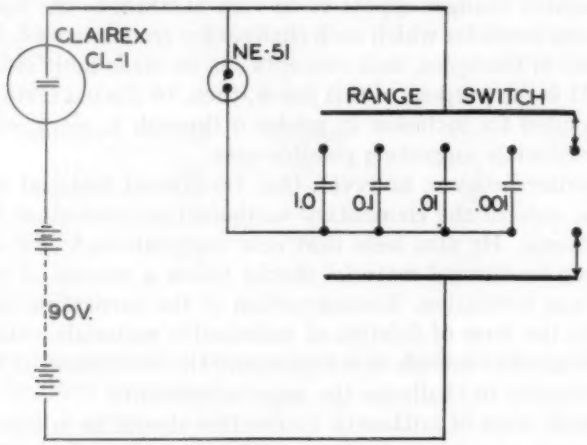
A Novel Meterless Light Meter

George Edgar Bradley
Western Michigan Univ.

Although of doubtful practical value the following device for measuring light intensity is extremely simple and quite inexpensive. Instead of indicating light intensity by an ammeter reading current through a photocell but actually calibrated in foot-candles, this instrument records light intensity by the flashing rate of a neon light. This neon indicator is part of an ordinary relaxation oscillator in which a selenium photo junction such as the Clairex-Cl-1 plays the role of the resistance. Variations in light intensity falling on the cell change the resistance and therefore the capacitor charging rate and the neon flashing rate in turn.



Experiments show that resistance varies almost inversely with the light intensity over wide ranges. The dark resistance of the cell being in the order of 100 megohms permits the use of several ranges. Change of range is accomplished by switching the capacitors being charged. Further range extension is accomplished by stopping down the aperture by means of a disk into which has been drilled separate holes of different area.



SCIENTISTS UNDERESTIMATE PLANTS' PHOTOSYNTHETIC POWERS

Scientists have been grossly underestimating the living plant's ability to carry on photosynthesis.

Photosynthesis—the remarkable process by which the plant changes the energy of sunlight into usable chemical energy or food—is still largely a scientific mystery. Researchers have been trying to solve the mystery so that man might duplicate this process in the laboratory and increase his food supply. Today, plants are a kind of "middle man" in the food cycle.

Now, a team of biologists reports, it seems that by studying plants in the laboratory, scientists have neglected an important factor—turbulence.

Turbulence, or rapid and irregular movement of the air or water, is probably responsible for higher photosynthetic rates in nature, the scientists report in the Journal *Science* (July 31).

Most previous estimates of photosynthetic yield have been based on experiments with tiny water plants enclosed in bottles. These results were then extended and said to apply to plants living under natural conditions. Such apparently is not so.

Water plants were sampled at five different depths in a channel where the water was about 27 feet deep. Photosynthetic activity was measured and compared with similar plants confined in bottles as in the earlier "classical" experiments.

Photosynthetic activity in the bottled plants was less than half that of the plants grown under natural conditions, the scientists found.

A New Look at Content and Its Placement in Elementary Mathematics

Herbert Hannon

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Much has been written concerning the need for change in the mathematics curriculum at all levels of instruction. Too often these recommended changes appear to be very abstract to the teachers at the various levels for which such changes are recommended. Perhaps, by the use of examples, such concepts can be made more clear to the reader. It is the purpose of this paper, then, to discuss certain topics recommended for inclusion in grades 6 through 8, along with illustrative materials suggesting possible uses.

The writer believes, however, that traditional material will form the basic core of the elementary mathematics curriculum for some time to come. He also feels that new materials and new ideas for presenting traditional material should follow a process of evolution rather than revolution. Reconstruction of the curriculum should be largely in the form of deletion of undesirable materials, extension of the curriculum to include new topics, and the enrichment of the present curriculum to challenge the superior students.

The basic aims of arithmetic instruction should be in terms of the development of a better understanding of the meanings of number and the number processes and certain competency in their use by the student. These should include competency in the use of common weights and measures, areas, and volumes. A study of percentage should be limited to the basic principles with a few important applications including interest, discount, and profit and loss. Consumer mathematics, as such, might well be left for a course in general mathematics at the senior high school level—when the student is more directly interested in such topics and in their application to his life.

In some cases the topics presented below represent merely a new approach to the teaching of traditional materials. Certain other topics are suggested here for inclusion in the elementary curriculum for the first time to the knowledge of the writer. Their merit will be determined by the teachers of the sixth, seventh, and eighth grades themselves.

Some suggested materials for sixth through eighth grades follow:

1. *Number systems using various bases*

To obtain a better understanding of our own decimal place-value system, the study of other equally usable systems is suggested. Cer-

tain rules apply to all place value systems using a specified base number. The rules are:

1) A certain number of units of one order make one unit of the next higher order.
2) Higher orders are written to the left of lower orders.
3) Empty orders are filled with a symbol for zero.

For comparison purposes a problem in addition and one in multiplication in each of three bases is given below.

Base Five (Symbols) 0 1 2 3 4		Base Ten (Symbols) 0 1 2 3 4 5 6 7 8 9		Base Twelve (Symbols) 0 1 2 3 4 5 6 7 8 9 t e	
Add	Multiply	Add	Multiply	Add	Multiply
321	314	86	84	72	70
432	×12	117	×7	99	×7
204	1133	54	588	46	410
2012	314	257		195	
	4323				

The same number value is represented in each of the problems in each of the three bases used.

2. *Modulo or "Clock" arithmetic*

In this system a specified base is used, but we keep only the residuals and "throw away" the value which we would normally carry.

For example: (modulo twelve)

$6+8=2$ $\qquad$ $9+5=2$
$5+7=0$ $\qquad$ $8+4=0$

A Modulo Arithmetic (Base Five) is illustrated below.

ADDITION FACTS

+	0	1	2	3	4
0	0	1	2	3	4
1	1	2	3	4	0
2	2	3	4	0	1
3	3	4	0	1	2
4	4	0	1	2	3

MULTIPLICATION FACTS

×	0	1	2	3	4
0	0	0	0	0	0
1	0	1	2	3	4
2	0	2	4	1	3
3	0	3	1	4	2
4	0	4	3	2	1

FIG. 1

Examples

Add	Subtract	Multiply	Divide
$1+3+4=3$	$1-2=4$	$4\times4=1$	$4\div1=4$
$2+2+4=3$	$1-3=3$	$2\times3=1$	$3\div2=4$
$4+2+1+3=0$	$2-4=3$	$3\times3=4$	$2\div4=3$

Of course the tables are read directly for addition and multiplication and in a reverse sense for subtraction and division.

Possible uses for such a system of counting might include any concept which is periodic and in which the period is of constant length. A good example would be in measuring time: 6 o'clock+8 hours=2 o'clock.

3. *Set concepts may be used to introduce fractions*

A set is defined as a collection of objects having one or more characteristics in common.

The basic fraction set, then, is that set of values which is equal to one whole.

$$1=\frac{1}{1}=\frac{2}{2}=\frac{3}{3}=\frac{4}{4}=\frac{5}{5}=\frac{6}{6}=\cdots=\frac{n}{n}$$

Sub-sets or portions of the above set are then developed which constitute the common fractions as we commonly think of them and use them.

$$\frac{1}{2}=\frac{2}{4}=\frac{3}{6}=\frac{4}{8}=\frac{5}{10}=\frac{6}{12}=\frac{7}{14}=\cdots=\frac{1\times n}{2\times n}$$

$$\frac{1}{3}=\frac{2}{6}=\frac{3}{9}=\frac{4}{12}=\frac{5}{15}=\frac{6}{18}=\frac{7}{21}=\cdots=\frac{1\times n}{3\times n}$$

$$\frac{1}{4}=\frac{2}{8}=\frac{3}{12}=\frac{4}{16}=\frac{5}{20}=\frac{6}{24}=\frac{7}{28}=\cdots=\frac{1\times n}{4\times n}$$

$$\frac{2}{5}=\frac{4}{10}=\frac{6}{15}=\frac{8}{20}=\frac{10}{25}=\frac{12}{30}=\frac{14}{35}=\cdots=\frac{2\times n}{5\times n} \qquad n\neq0$$

Using set concepts to add fractions, the common denominator concept is developed as below.

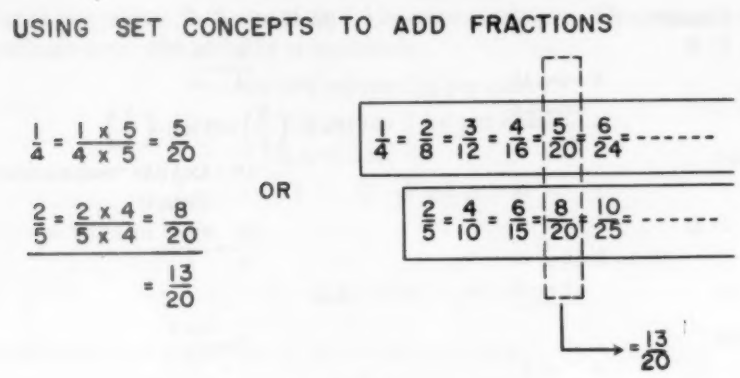


FIG. 2

Set intersections may be used to generalize the process of obtaining a common denominator. The "overlap" of the circles represent numbers which may be used as common denominators when halves and thirds are added.

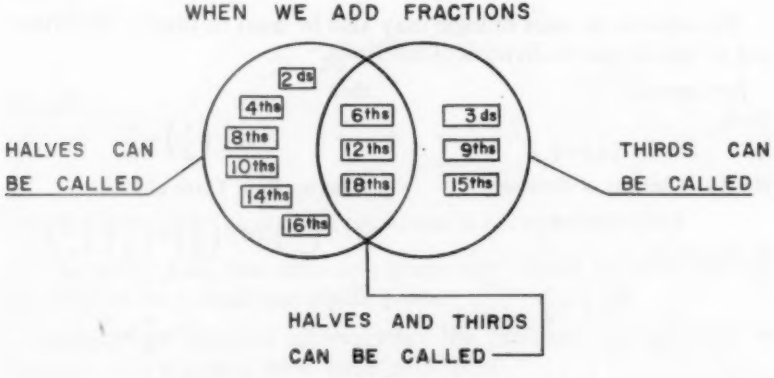


FIG. 3

4. *Axioms or rules of logic are used to solve conditional equations which become meaningful "if then" situations*

These basic rules are:

1) If $a=b$ then $a+c=b+c$.
2) If $a=b$ then $a-c=b-c$.
3) If $a=b$ then $ac=bc$.
4) If $a=b$ then $\frac{a}{c}=\frac{b}{c}$ $(c\neq 0)$.

The solution of equations using these axioms or rules of logic should be introduced early in the seventh grade in the opinion of the writer. Then we can justify the computational procedures which are used.

Examples:

1) If

$$N-6=10$$
$$+6=+6$$

then

$$N=16$$

2) If

$$N+8=14$$
$$-8=-8$$

then

$$N=6$$

3) If

$$\tfrac{1}{3}N=8$$
$$(3)\cdot(\tfrac{1}{3}N)=(3)\cdot(8)$$

then

$$N=24$$

4) If

$$\frac{N}{4}=\frac{5}{3}$$
$$(3\times4)\cdot\left(\frac{N}{4}\right)=(3\times4)\cdot\left(\frac{5}{3}\right)$$
$$3N=4\times5 \text{ (the "cross-multiply" concept)}$$
$$\frac{3N}{3}=\frac{4\times5}{3}$$

then

$$N=\frac{4\times5}{3}$$

(the "Rule of Three").

The axioms or rules of logic may also be used to justify the inverting of the divisor in division of fractions.

For example:

Since

$$\tfrac{2}{3}\times\tfrac{3}{4}=\tfrac{1}{2}.$$

By the definition of division

$$\tfrac{1}{2}\div\tfrac{2}{3}=\tfrac{3}{4}.$$

In general if

$$N=\frac{a}{b}\div\frac{c}{d}$$

then

$$(N)\cdot\left(\frac{c}{d}\right)=\frac{a}{b}.$$

Next by Rule Three of Logic

$$\left(\frac{d}{c}\right)\cdot(N)\cdot\left(\frac{c}{d}\right)=\left(\frac{a}{b}\right)\cdot\left(\frac{d}{c}\right)$$

or

$$N=\frac{a}{b}\times\frac{d}{c}.$$

5. *Inequalities find many applications in everyday life*

Once they are introduced, they may be used to interpret the size of fractions not easily comprehended directly by the student.

$a < b$ means "a" is not as great as "b".

$b > a$ means "b" is greater than "a".

$a \neq b$ means "a" is not equal to "b".

More precisely, $a<b$ means $a+N=b$: and $b>a$ means $b-N=a$, where N is some number which will make an equality out of what had been expressed as an inequality.

The writer is using the following grocery store problem to illustrate the basic principle. A comparison is made of the cost of corn

flakes per ounce in 8-ounce and 12-ounce packages. The prices per package were 19¢ and 25¢ respectively.

8 oz. for 19¢ means $2\frac{3}{8}$¢ per ounce.

12 oz. for 25¢ means $2\frac{1}{12}$¢ per ounce.

$2\frac{3}{8} > 2\frac{1}{12}$ means

$2\frac{1}{12} + N = 2\frac{3}{8}$ or $2\frac{3}{8} - N = 2\frac{1}{12}$.

By the rules of logic

$$N = 2\tfrac{3}{8}\text{¢} - 2\tfrac{1}{12}\text{¢} = \frac{7}{24}\text{¢}$$

additional cost per ounce in the 8-ounce package.

An interpretation:

First

$$\frac{7}{24} < \frac{8}{24} \quad \text{and} \quad \frac{8}{24} = \frac{1}{3}.$$

Also

$$\frac{6}{24} < \frac{7}{24} \quad \text{and} \quad \frac{6}{24} = \frac{1}{4}.$$

Finally

$$\frac{1}{4} < \frac{7}{24} < \frac{1}{3}$$

which means that the savings per ounce is between $\frac{1}{4}$¢ and $\frac{1}{3}$¢.

6. *The writer feels that ratio and proportion should be dealt with extensively in the seventh and eighth grades*

Perhaps one third of all everyday life problem concepts can be thought of in terms of these basic principles.

A ratio is defined as a comparison between "like" quantities or between "related" quantities. A proportion, then, is an expression of an equality of two ratios. Reasoning by proportion also may be thought of as reasoning by analogy.

(a) The same grocery store cost comparison problem may be solved also by proportion.

Quantity ratio = cost ratio

$$\frac{8}{12} = \frac{19}{N} \qquad N = \frac{12 \times 19}{8}$$

$$N = 28\tfrac{1}{2}$$

The value of N in this case represents the upper limit of the amount

which might be paid for the 12-ounce package to realize a saving over the 8-ounce package cost.

This conclusion now leads to a *solution set.*

Since

$$28\tfrac{1}{2} > 28 > 27 > 26 > 25 \cdots ,$$

then 28¢, 27¢, 26¢ and 25¢ are all more or less desirable prices for the 12-ounce package.

(b) Time, rate, distance problems are also examples of ratio concepts expanded into proportions to determine one of the values which is unknown. Three distinct type problems are obtained.

$$\frac{D_1}{D_2}=\frac{T_1}{T_2} \quad \text{or} \quad \frac{D_1}{D_2}=\frac{R_1}{R_2} \quad \text{and} \quad \frac{T_1}{T_2}=\frac{R_2}{R_1} \text{ (inverse)}$$

It must be realized here that the value of some other variable representing the value of the ratio is in each case being held constant.

(c) The ratio π may be obtained by direct measurements.

$$\pi=\frac{C_1}{D_1}=\frac{C_2}{D_2}=\frac{C_3}{D_3}= \cdots =\frac{C_n}{D_n}$$

(obtain an average value for these ratios).

(d) Finally, another example of the utility of ratio is in the teaching of percentage by means of the proportion concept. The following example illustrates the procedure.

$$6 \text{ is } 75\% \text{ of } 8$$

This statement of fact leads to the three common types of percentage.

Type I. What number is 75% of 8?

$$\frac{N}{8}=\frac{75}{100} \qquad N=\frac{8\times 75}{100}=6$$

Type II. 6 is what % of 8?

$$\frac{6}{8}=\frac{N}{100} \qquad N=\frac{6\times 100}{8}=75 \text{ which means } 75\%$$

Type III. 6 is 75% of what number?

$$\frac{6}{N}=\frac{75}{100} \qquad N=\frac{6\times 100}{75}=8$$

(e) Finally, a comparison of areas and volumes of similar figures can also be made by extended proportion concepts.

7. *Limit concepts found in elementary arithmetic*

The concept of limit is perhaps the most obscure of all of the topics

listed in this paper. If, however, a broad interpretation of this concept of limit is taken, the topic need not be as profound as we find it to be in advanced mathematics.

We speak of a speed limit, a city limit, and many other limits in everyday conversation. In each case the limit represents a boundary value which we can approach from one or more directions just as we might approach a city limit from either within or without the city. No more profound interpretation is intended in the following discussion.

The symbol for a limit used in this presentation will be an arrow. $A \rightarrow B$ is read, A aproaches B.

Further, as $A \rightarrow B$, C might approach D, as, for example, when we approach the city limit from without the city our speed *should* approach the speed limit of the city as an upper bound. This type of analogy cannot be carried any further, however.

(a) Evaluating π by various upper and lower limits which have been used:

Estimates		*Conclusions*
$3 < \pi < 4$	(in Bible)	$\pi > 3$
$3 < \pi < 3\frac{1}{7}$	(early Greek)	$\pi > 3.1$
$3 < \pi < 3.142$	(decimal equivalent)	$\pi > 3.14$
$3\frac{10}{71} < \pi < 3\frac{10}{70}$	(Archimedes)	$\pi > 3.141$
$3.141 < \pi < 3.143$	(decimal equivalent)	$\pi > 3.1415$
$3.1415 < \pi < 3.1416$	More modern estimate	$\pi > 3.1415926$
		$\pi = ?$

(b) Using the limit concept in finding the area of a circle.

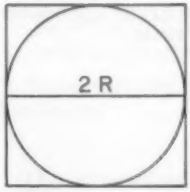


FIG. 4

1) The area of the circle < area of the square $= 4R^2$.

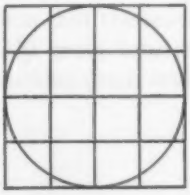
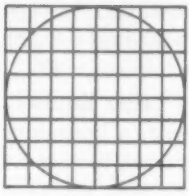


FIG. 5

Approximate area of the circle can be found by counting the fully enclosed squares and "estimating" the partial squares enclosed.



Successively better estimates can be made by using smaller squares each time.

FIG. 6

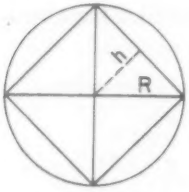
Conclusion:

A of 0> area of full squares enclosed by the circle.

A of 0< area of full squares and area of squares partially enclosed.

NOTE: No additional refinement of the above process is possible by elementary means. The limit desired cannot be reached in actuality except by the use of the concepts developed in the calculus.

2) A better process of finding the limiting value of the area of the circle by elementary means is through the use of triangles enclosed in the circle.



A of 0>the area of the enclosed ▲.

FIG. 7

With additional triangles the height of each △ approaches the value of the radius of the circle.

$$\text{Limit } h \to R$$

Also the sum of the bases (b) of the triangles approaches the value of the circumference of the circle.

$$\text{Limit } b \to C.$$

FIG. 8

But

$$A \text{ of } ▲ = \tfrac{1}{2}\, bh$$

(c) The value of the area of the sum of the enclosed triangles approaches the value of the area of the circle.

Or

$$A \to \tfrac{1}{2}CR$$

$$A \to (\tfrac{1}{2}) \cdot (2\pi R) \cdot (R) \to \pi R^2$$

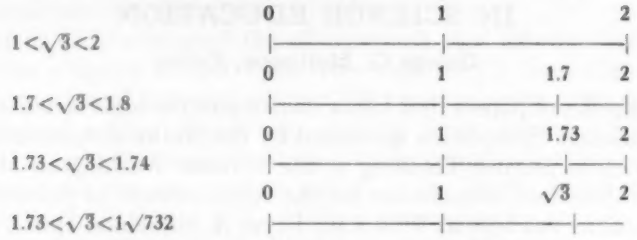
finally

$$\text{Limit } A \text{ of } 0 \to \pi R^2.$$

NOTE: $\pi R^2 < 4R^2$ (our initial estimate).

(d) Approximating square roots as a limit process. Successively

more accurate estimates may be used.



Of course we can never express the square root of 3 exactly.

(e) Approximate computation as a limit concept.

All measurements represent a limit concept based upon the ability of the measurer to read digits on a scale, the degree of accuracy required, and the precision of the measuring instrument.

1. *Example:* Find the weight of 26 articles each of which weighs approximately 2.3 ounces (correct to nearest tenth of an ounce).

2.25<2.3<2.35

The outer numbers in the inequalities represent the upper and lower limits of the measurement values which will be accepted. Now computing the upper and lower limits values.

2.25 oz.	2.3*	2.35
×26	×26	×26
13 50	13 8*	14 10
45 0	46*	47 0
58.50 oz.	59*.8*=60* oz.	61.10 oz.

(The star (*) indicates a figure about which the accuracy is in doubt.)

Conclusion:

58.50<60<61.10
or 60 oz. is a reasonable estimate of the value.

Of course narrower limits can be obtained if greater precision of measurement is indicated.

Summary

The above topics and the illustrations used are merely indications of the possible variations in both approach and materials which may be used in taking a new look at elementary mathematics. It is certain that the teachers of the grades indicated will find many and possibly more interesting examples to illustrate these concepts at the various grade levels where they might apply.

SYMPOSIUM ON RECENT RESEARCH IN SCIENCE EDUCATION

George G. Mallinson, Editor

The series of papers that follow constitutes the reports delivered at the Research Symposium sponsored by the National Association for Research in Science Teaching at the Seventh Washington Meeting of the American Association for the Advancement of Science. The symposium was held at 9:00 A.M., Foyer A, Shoreham Hotel, Saturday, December 27, 1958.

The reports consisted of reviews and implications of recent research in science education at the elementary, secondary, and college levels.

REVIEW OF RESEARCH IN ELEMENTARY SCIENCE EDUCATION

Betty Lockwood Wheeler

Mt. Pleasant, Michigan

Fifteen studies related to elementary science education are reviewed in this report. Of these, six were classified as experimental, six as analytical, and three as synthetic (these categories were established for science education research by the National Association for Research in Science Teaching).

Experimental Studies

Bixler (1) investigated the variables involved in pupil acquisition of science information and science attitudes. He investigated five variables: (a) teacher attitude toward science, (b) teacher degree of authoritarianism, (c) teacher attitude toward desirable teacher-pupil relations, (d) intelligence of student, and (e) sex of student. Sixty-two intermediate grade-level teachers were involved in the testing program and were administered the Edwards and Kilpatrick's Attitude Toward Science Scale, the California F-Scale, and the Minnesota Teacher's Attitude Inventory. 1767 children took pre-tests and post-tests involving science information and science attitudes. The scores obtained by the children were then compared with the scores obtained by the teachers on the three tests administered the teachers, and also with the sex and intelligence of the children themselves.

The results indicated a definite relationship between the teacher's attitude toward science, and (1) the children's informational test scores and (2) the scores obtained by the children on the attitude tests. Both science information and science attitudes were related to

children's intelligence. Acquisition of science attitudes by children is thus an obtainable educational objective.

Sostman (13) evaluated the effectiveness of a six-year nutrition education program in K-6. Objectives were to: (1) bring about improvement in food habits of children, (2) improve health (appearance, growth, and general alertness), and (3) bring about curriculum changes as a result of an in-service education program for the teachers involved. Children who went to schools in the Puerto Rican section of New York City, and 80% of whose parents spoke only Spanish, participated in the study. Results showed a definite increase in the number of children eating breakfast, and an improvement in the breakfast pattern itself. There was also an increased participation in the school lunch program (25% to 42%). Significant differences showed up in growth patterns of children participating in the program as compared with those in similar school areas.

Students in grades 4, 5, and 6 in Boston served as subjects for an investigation into the learning of scientific concepts and principles in the areas of Light and Sound. A planned teaching program was initiated as an in-service workshop by Nelson (8), in which the teachers were given instruction in the two areas of Light and Sound. None of the participating students had been taught physical science before. Individual student interviews furnished bases for determining pre-conceived ideas regarding light and sound. Tests were given prior to and upon completion, and the gains in understanding of principles and concepts were calculated. Neither socio-economic status nor sex of the students seemed to affect the scores significantly.

Morrone (6) compared the social-living approach (integrated social studies and science) with the separate subject approach for teaching social science and elementary science to determine which method produced better results at the fifth grade level. The integrated plan evolved around three basic problems: 1) How can community planning help to solve the problems of community living in our County?; 2) How have improved methods of transportation affected us?; and 3) How can we reflect our growing sensitivity to beauty and the finer things of life? The control group followed the basic texts closely. Comparable testing was used with both groups. The correlated approach based on activities was proven superior to the traditional text approach.

Neal (7) attempted to determine adequate methods of science inquiry in children, grades 1–6, in the Laboratory Schools at Colorado State College. Steps involved in method of science inquiry were defined. A series of 61 techniques were included which promoted ability in growth of children to use these science inquiry methods. Evaluation of these techniques came from examinations of anecdotal records,

record books, records of creative work, and objective type paper and pencil activities. Results showed that young children can develop skills in organization, can establish goals, form hypotheses, and evaluate them.

Preston (10) compared learning of German and American children of specific interrelations between bodily position (right and left), the four cardinal directions, and the position of the rising and setting sun. Four questions regarding these items were answered by 400 sixth grade pupils in Hamburg, Germany and over 600 sixth graders in Philadelphia. Half of the total children included were in the upper 27% of population in respect to intelligence, and half were in the lower 27%. Results showed consistently higher scores by the American children. However, their absolute knowledge was not impressively higher.

Analytical Studies

Mackiewicz (5) designed a curriculum guide in elementary science for the first six grades of Vermont Schools. She planned an orderly sequence of subject matter with appropriate activities and experiences based on four units of study per grade, 2 of biological science and 2 of physical science. Concepts, problems, and understandings were developed. This guide is to be used on a trial basis in selected Vermont schools, then revised before Statewide use.

Sims (12) developed and evaluated an inservice program in elementary science for elementary teachers in Kansas. A series of meetings were conducted to provide information and assistance. Participation of teachers was on a voluntary basis. At each meeting one or more broad topics pertaining to science in the elementary school was discussed with demonstrations. Pupils of the participating teachers, plus pupils of non-participating teachers, were tested at intervals, as were the teachers themselves. Controls and participating classes and teachers were matched. Pretests and posttests were given. Pupils in the experimental classes achieved significantly more on the post examinations.

Ramsey (11) conducted a study through Ohio State University, concerning children's contributions to the elementary-science program through the sharing of their experiences. A tape recorder was used to record the content of the sharing experience, held usually at the beginning of the school day. A total of 832 children, in grades 2, 4 and 6 were the subjects. Outcomes showed that a wide variety of out-of-school experiences involved science, including trips, communication activities, recreation, and activities with animals. It was also shown that younger children (grade 2) tended to share experiences more than the older ones in grades 4 and 6. References to science

phenomena were more frequent in biological science than in physical science. Science principles, as such, were not shared by the children at any of the grade levels checked. However, a total of 194 science concepts, and 376 science clues related to 17 science concepts, were identified.

Young (15) analyzed Atomic Energy Concepts of third and sixth graders as revealed through interviews and questionnaires. 75 third graders were interviewed using a guide sheet, pictures and diagrams. The same information was solicited from 68 sixth graders via a questionnaire containing pictures and diagrams. Children were questioned regarding sources of their information. The results showed that boys had more understanding of atomic energy than girls, the main source of information being television. There was a wide range of individual differences in readiness for science and in misconceptions. A better controlled study might have included the two grade levels for each method of presentation since the interview method is more difficult to control and to limit only to the information contained in the questionnaire.

Blanc, in collaboration with Lous and Mathes, (2), summarized recent trends in science education at the elementary and secondary levels. Literature published during the past 15 years was surveyed in light of: (1) subject matter; (2) grade placement and (3) general trends. Little uniformity was evidenced regarding selection of subject matter for grade levels. A steady growth in curriculum development to include elementary science was found with objectives fairly well established. Implementation of objectives was not assured however. Science principles were introduced at all grade levels and showed increasing difficulty with grade advancement. There appeared no evidence as to agreement on relationships of grade level and specific science experiences. The general trends were (1) that continuous K-12 science programs are generally accepted, (2) that courses of study are organized with major science principles in mind, and (3) there is general reconsideration of general science courses at the ninth and tenth grade levels in an attempt to provide for the non-talented science student.

Verrill (14) surveyed the program of elementary science in grades 5–8 in schools within four school districts of Cook County, Illinois in 1956. Teacher problems relative to time allotment, science concepts and outcomes, usable materials, were explored. Pupil interest in the various phases of science were surveyed. Results showed that application of science experiences rated highest; experiments and field trips were judged to be the most stimulating and workable; whereas reading about science in textbooks was not rated highly as a pupil science interest.

Synthetic Studies

Branley, (3) developed a teaching aid which provides a basis for a course in astronomy at the Hayden Planetarium for elementary teachers. The core of the project is a series of activities built around some of the concepts involved in studying astronomy. Concepts included are: change is continuous in the universe; motion is universal; the universe is very large; and man obtains knowledge through his senses. Activities to aid development of these concepts were chosen for classroom ease, without need for elaborate equipment. The course was first presented at the Hayden Planetarium in the fall of 1957.

A reference book entitled *An Ocean Geography for Children* was the outcome of the study by Caruso (4). While designed for upper elementary grades, it is also usable for teachers. The material emphasizes concepts relative to the ocean, its inhabitants and its uses. This study represents a compilation of material that was checked for comprehension and vocabulary by sixth graders and their teachers.

Another study, developed as a science teaching aid by Notkin (9), implemented the New York City Course of Study in Elementary Science. Its purpose was to provide a series of experiences for K-grade 6, covering seven science areas: Earth and its Resources, Weather, Transportation, Communication, Earth in Space, Magnetism and Electricity, and Plants. The detailed descriptions of the experiences should assist elementary grade teachers with meager backgrounds in elementary science to do better teaching in this field.

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Implications of the Findings of Recent Research in Elementary Science Education

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Recent research studies on the teaching of science in the elementary school have touched upon almost every aspect of science education. And almost all of these studies, following a conventional research-reporting procedure, indicate further needed research. This is an admirable and helpful practice. Indeed, it touches at the very heart of scientific inquiry to assume there is more to be learned about natural phenomena and to point as specifically as possible to those areas of needed knowledge. Thus, most of the studies reported recently are scientific in that sense. Conclusions are stated tentatively and there is more to be learned. For example, following upon the Fourth Annual Review of Research in the Teaching of Science in the Elementary School.[1] Jacqueline Buck Mallinson, in her articles "What Have Been the Emphases in Research in Elementary Science During the Past Five Years?"[2] and "What Research in Science Education is Needed to Strengthen the Elementary Science Program?",[3] very

[1] Hubler, Clark *et al.* "Review of Recent Research in the Teaching of Science at the Elementary School—Level I." *Science Education*, XL (December 1956), 339–41.

[2] Mallinson, Jacqueline Buck. "What Have Been the Major Emphases in Research in Elementary Science During the Past Five Years?" *Science Education*, XL (April 1956), 206–8.

[3] ———. "What Research in Science Education is Needed to Strengthen the Elementary School Science Program?" *Science Education*, XL (December 1956), 369–71.

deftly identified the major areas of need in science research. In relation to the purposes of elementary science instruction she writes that previous studies seem to point to the fact that there is general agreement with respect to the areas most commonly taught, but that studies fail to show a common agreement with respect to the purposes of science instruction. She recommends that research is needed to identify in simple terms the things that science should help children *do* better. Once these attitudes and skills are identified and accepted by elementary teachers as important, the emphases can be put on developing those skills and "elementary school children should not be expected to study every area of science or remember every science fact they study."[4] This observation is accepted generally by science educators, but science curriculum committees in many places continue to be preoccupied with organizing the major areas of classified science knowledge in sequences so that all children will have an opportunity (and often the obligation) of studying something about everything. We shall return to this problem of curriculum organization later.

Mallinson suggests needed research, also, in the methods of teaching elementary science, evaluation in elementary science and in the training of science teachers and summarizes thus:

"In the future it would seem that researchers might well direct their efforts toward identifying the specific purposes of elementary science instruction; developing evaluative techniques that will measure accurately the outcomes of science instruction; and developing programs of pre- and in-service training that will be of value in preparing elementary school teachers to teach science effectively."[5] Likewise, the committee which prepared the Fifth Annual Survey of Research[6] placed emphasis on needed research. Studies in the area of problem solving were proposed on:

(1) Techniques of setting up problems to be solved in a unit of work.
(2) Learning experiences designed to help pupils identify problems.
(3) Processes involved in proposing and testing hypotheses.
(4) Learning experiences designed to help pupils interpret evidence.
(5) Learning experiences designed to help pupils draw conclusions from data.

Betty Wheeler in her summary of "Research in Science Teaching at the Elementary Grade Levels"[7] has identified over a half-dozen very significant problems for future research. One of these touches again upon the problem which is preoccupying science curriculum workers: Does a more selective treatment of a few science areas and principles at each grade level yield better educational outcomes than treating many science areas and principles in each grade?

[4] *Ibid.*, page 370.

[5] *Ibid.*, page 361.

[6] Obourn, Ellsworth S., *et al.* "Fifth Annual Review of Research in Science Teaching." *Science Education*. XLI (December 1957), 404.

[7] Paper read at NSTA Section of AAAS, Washington, D. C., December, 1958.

It is important that we remember, too, the two excellent summaries of research, *Elementary School Science: Research, Theory and Practice*,[8] by Dunfee and Greenlee and *What Research Says to the Teacher, Science in the Elementary Schools*,[9] by Craig. Persons planning research in elementary science will want to examine each of these booklets carefully. The Dunfee and Greenlee report not only cites nearly 200 studies but discusses some of the implications for science teaching. Craig's summary is a distillation of generalizations and guiding concepts for development of science programs based on research and long experience.

Areas of needed research, then, are well identified in the research summaries referred to above. But our problem here is to discuss the implications for science teaching of those research studies which *have been conducted*, not to identify further needed research.

Therefore, at the risk of over generalization and personal error, I should like to discuss briefly several beliefs, practices and procedures in the teaching of elementary science which we can accept with confidence because research has given evidence that we are on the right track.

Skills of Inquiry

We have ample evidence from several studies (Hill,[10] Neal,[11] and others) to show that children learn to do those things which they are given an opportunity to do. For example, children can develop skills in organization of information, can establish goals, form hypotheses. They can collect data from a variety of sources and can improve their ability to select and analyze data relevant to questions being studied. They can do these things if given an opportunity to do them with guidance and with purpose. Perhaps the greatest lack in science teaching is the absence in typical classrooms of opportunities for children to engage in real investigations, to seek answers, to solve problems. If this is a goal to be achieved, (and there is almost universal agreement that it is), then classroom procedures, the teacher's orientation and the materials prepared for teachers, should all point to the importance of this principle—that children learn the skills of inquiry if given the opportunity to learn them. They do not learn them without being given a chance. Teachers must develop classroom procedures which not only permit but foster experience in making investigations

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[8] Dunfee, Maxine and Greenlee, Julian, *Elementary School Science: Research, Theory and Practice*. Washington, D. C.: Association for Supervision and Curriculum Development, 1957. 67 p.

[9] Craig, Gerald, *What Research Says to the Teacher: Science in the Elementary Schools*. Washington, D. C. American Educational Research Association, NEA. 1957. 33 p.

[10] Hill, Katherine E. "Children's Contributions in Science Discussions." New York, Teachers College, Columbia University, 1946.

[11] Neal, Louise A. "Techniques for Developing Methods of Scientific inquiry in Children in Grades 1 Through 6." Unpublished doctoral dissertation, Colorado State College. 1957.

and in problem solving. The responsibility for helping teachers acquire an awareness of what is involved in this kind of teaching rests with teacher training institutions, and school systems in their inservice programs.

In my opinion, the TV science teaching which I have observed, provided little opportunity for children to invent experiments, to speculate, to test hypotheses, to use materials, and to raise questions for exploration. These things typically are done by the TV teacher but not by the children. Children learn science facts from TV that is known. Perhaps research will yet show that they likewise learn from TV the skills of inquiry, experimentation and investigation. But, as of 1958, TV teaching is too much like the teaching of thousands of classroom teachers with respect to the teaching skills which we are now discussing, namely skills involved in setting a procedure and atmosphere for permitting children to *do* what we want them to *learn* to do.

Attitudes

There is a definite correlation between the teacher's attitudes toward science and children's attitudes.[12] This has many implications. First, teachers of science must be interested and enthusiastic about science. Their preparation to teach science should give them knowledge and resourcefulness so that they will be confident. If a teacher is confident, there is greater likelihood that an atmosphere of scientific inquiry will prevail in the classroom than if the teacher is timid and restricted both in knowledge and in awareness of the methods of science.

An attitude may be thought of as a predisposition to behave in a certain way. For example, if a person withholds judgment because he believes it important to withhold judgment until evidence clearly indicates what judgment is correct, his attitude is modifying his behavior. If he makes premature judgments, jumps to conclusions and habitually overgeneralizes, he certainly does not possess an attitude of withholding judgment, much as he may profess that he does. Throughout our science teaching we must bring to life by example the attitudes which derive from the methods of science. One further example on this point. Teachers who in their science teaching place major emphasis day after day on extracting from children "correct" answers which are recorded in books or in the minds of more experienced or knowledgeable people, develop an attitude in children that science is just that—a process of digging out of authoritarian sources the answers

[12] Bixler, James. "The Effect of Teacher Attitude on E'ementary Children's Science Information and Science Attitudes." Unpublished doctoral dissertation, Stanford University. 1957.

already arrived at by other persons. Certainly we can say with confidence that habits of open-mindedness, withholding judgment, speculativeness and the like have faint hope of realization in classrooms where these behaviors are not expected nor recognized as important aspects of scientific learning. Or putting it positively, as we said earlier, children do learn these behaviors in situations where there is an expectation that they do so and where there is a premium placed on them.

The Content of Elementary Science

Several investigators have indicated that there is great variation in the science subject matter for specific grades when curriculums from different schools are compared. But as Craig points out "an analysis of the content of the entire span of the elementary school—reveals an emerging and large body of subject matter in science which is common to must curriculums."[13]

Research does not show, however, that there are certain areas of the environment which either because of the nature of children or the nature of learning must of necessity precede other areas. Rather research, bolstered by the empirical evidence of teachers, tends to show that children at any age level can study with profit something about all areas of the environment. There are, or course, easier and more difficult science concepts. The easier concepts can be so identified only when we discover that younger, less experienced and less intelligent children can indeed comprehend them. The ability of children to comprehend a specific concept is not so much a function of age or grade in school as it is of experience and intelligence. That leaves us with the responsibility of helping each child in each grade move toward a more mature understanding *for him* of concepts that are important.

As to which science areas should be studied before others, it is my own judgment that any attempt to find a single pre-determined sequence of science content areas or even concepts within areas for children everywhere is a will-o-the-wisp search.

It is appropriate and necessary, however, for curriculum workers to continue to identify science concepts which in our best judgment are important for children to understand. And it facilitates planning in a school system to have a carefully outlined, flexible sequence of science areas for study from grade to grade. However, the major concepts and generalizations of science can be learned in different ways through the use of different specific content areas. That is, there are many roads to Rome. Children in one city or region may learn the major science concepts by studying different content areas from those

[13] Craig, *op. cit.*, p. 8.

studied by pupils in other cities or regions. It is not so much a matter of research results as of opinion whether children everywhere *should* know the *same* science facts. We know that there is more to know than any child anywhere can know. Therefore, there must be some selection of what is to be studied in school. As we make selections with children of what we are to study, we will by chance alone develop diversity of knowledge. I think this diversity is good. We have no research that I know of that shows that all children should be pressed into the same science curriculum mold, especially the content part of it.

Perhaps we do need additional research to discover what constellation of experiences and knowledge lead to the production of scientists. We know, however, that we do not want all children to be professional scientists. We do want all of them to be wiser and more responsible citizens. We have several studies which show that teaching science in the elementary school can bring about changes in the behavior of children.[14] But the desired changes don't occur just by chance. They do occur when teaching is carried on in ways so that children have opportunities to behave in ways that lead to the desired objectives.

It follows, then, that we must continue to stress those attitudes and skills which are needed by responsible, thinking citizens and we must do whatever we can to help teachers in ways that bring about these skills of scientific inquiry. This sounds like an old refrain. And it is. But as I have said several times, and with due regard to thousands of excellent teachers, it is still all to uncommon a refrain in classrooms where teaching occurs. I think the one single greatest need in science teaching today is to achieve more teaching which with imagination translates our stated and accepted purposes into living evidence of success in the behavior of our students.

[14] For one such study see Edna Ruth Sostman's "An Evaluation of the Methods, Techniques, and Findings Used During a Six Year Nutrition Education Program in a City School." Unpublished doctoral dissertation, Teachers College, Columbia University. 1957.

Review of Research in Secondary Science Education

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In an annual review of research in secondary science education for 1956–57[1] twenty-two research studies were reported; for the 1957–58 period seventy-five were found. This spurt in research is just one indication of the increase in interest and activity in high school science teaching. The numerous new developments in science courses and in out-of-class science activities point to the same thing. And

[1] Obourn, Ellsworth S. and others, "Fifth Annual Review of Research in Science Teaching." *Science Education*, XLI (December 1957), 375–411.

certainly in the immediate future with the funds provided by the National Defense Education Act there will be no decrease in activity in science education.

The seventy-five different studies reported were divided into seven categories. The first of these arbitrary groupings included studies related to the curriculum.

The Curriculum

Principles of science were the subject of several of these investigations. These studies indicate the importance of principles for organizing a wide variety of new science courses. One was made to determine principles of nuclear energy of importance to United States citizens; another was made to determine what basic facts and concepts of science are of importance for general science courses and to determine value of students' backgrounds for developing understandings of these concepts. One study provided materials for learning important biological principles. Still another was made in order to establish a list of science and mathematics principles applicable to industrial jobs.

How science misconceptions can be used in selecting subject matter for biology and physical science courses was the subject of another investigation.

There were three significant synthetic studies for this period. One of these was *Introductory Physics*, a series of 162 films, narrated by White of the University of California. Evaluation studies of this series have recently been completed by a committee at the University of Wisconsin.

The following conclusions were drawn as the result of a study of this series: learning was not significantly greater for the film-using group over the non-film-using control; retention after three months was slightly better for the non-film-using group; teachers who used the films learned much physics in this way; and differences up to the point of 18 credits in physics training of teachers are reflected in achievement of pupils.

In another study, the Physical Science Study Committee of the Massachusetts Institute of Technology has produced a new and widely used type of physics course. This course is based on the quantum, rather than the mechanical approach to physics. Equipment for teaching these concepts has been developed, a four-volume textbook prepared, and a series of seventy films is now under way. Evaluation of the project will be conducted by Educational Testing Service.

A third film project is *An Introductory Course in Chemistry*, completed in time for the 1958–59 school year, under the direction of Baxter at the University of Florida.

Teaching Methods

Definitive studies of the merits of television and other audiovisual aids in science teaching have yet to be made. One study will indicate a statistical superiority in the use of a medium, and another that there is no such superiority. Two studies in this period, however, both indicate that certain visual aids are equally effective when used with pupils of high ability as when used with those with low ability.

In an analysis of selected items from New York Board of Regents high school examinations, it was found that questions giving students the most trouble were those requiring application of facts and principles. The investigator concluded that teachers should make greater effort in helping students understand relationships and place less emphasis on learning facts.

Predictions of Success

Investigators in this group are not in agreement as to the best methods of predicting success in high school and college science courses. Varying degrees of accuracy are assigned to scores on achievement tests, course grades, home environment, interests, etc. as bases for counseling students.

High school physics courses were found to make a significant contribution to understandings of 24 principles of science, whereas the contributions of junior college survey courses were relatively small.

Education of the Talented

This is the category which shows the sharpest increase in amount of research in the past year. One study indicates that the value in any method used to teach the talented lies in placing responsibility on the individual student; several recommend early identification and homogeneous grouping of this group; another notes the relatively small number of girls in the group; and in one study a set of criteria was set up for up-grading science reading material for these students.

Status of High School Science Enrollments, Materials, and Qualifications of Teachers

The results of a nationwide survey by the Research Division of the National Education Association of the status of science in the United States indicate that percentage-wise more American high school students are studying science than ever before, and that the quality of science instruction in most large high schools is high. Eleven regional studies, however, indicate that although the national picture is improving with respect to the number of students enrolled in science courses, in equipment and facilities for these courses, and in the quali-

fications of those teaching them, many areas of the country are below acceptable minimum standards.

Training of Teachers

Two summer programs for science teachers were evaluated. In one it was revealed that the participants were better qualified than for the country as a whole, but that there is much need for graduate courses in methods and especially in content. In the other study there was indication of tangible improvements in science teaching such as better use of community resources and development of new laboratory programs, as well as intangible improvements in attitudes and morale.

In an attempt to match content used in teaching high school science units and with courses in a teacher training institution, it was found that the required college-level courses did not provide an adequate background. In another study it was found that relatively few institutions allow the high school chemistry teacher to take the science courses he really needs. A fifth year of training for science teachers was recommended in one study which pointed up the deficiencies in science background of high school teachers.

Miscellaneous

A study of the status of school science fairs indicates that the typical science fair is a small enterprise, that it is a relatively new project, and that it was sponsored by one of a variety of organizations (newspapers, professional societies, industry, etc.).

A national student science awards program was the subject of a study which confirmed findings and opinions of others with regard to the backgrounds, activities, and qualifications of highly able and motivated science students. The investigator concluded the program was achieving several of its objectives and made suggestions for refinement of the competition.

A study of popularity with general science teachers of the double-period class and the single period indicates that the former is favored. Preference was shown for double period because it facilitates laboratory work and correlates with mathematics.

Implications of the Findings of Research in Secondary Science Education

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The implications of research in science teaching have broadened

tremendously with the advent of the space age. Since our very survival is dependent upon the quality of science education that our future scientists and engineers will receive in the coming years, our research in this area becomes terribly important. It is not surprising that President Eisenhower, in recently addressing the nation on TV and radio, asked that an efficient program be developed for identifying gifted students and that proper provision be made for instructing them and assisting them economically. He spoke of aptitude tests and methods of teaching—areas formerly confined to the educator alone. In short, implications of research in science education need to be considered in the light of who will be affected by and who will be the consumer of the research. This idea was clearly expressed in 1937 by Dr. William H. Bristow in an address before the American Educational Research Association entitled "Educational Research for the Consumer",[1] in which he stated:

"Education is so complex that educational research has difficulty in knowing just what group or groups of consumers are to be most concerned with any particular piece of research. An analysis of the field reveals at least seven such groups.

1. The first group may be classified as technical—those trained in the field of research and actively engaged in research studies. This is an important but a relatively small group.
2. The second group is composed of administrators and supervisors, a small selected group. It is for this group that most of the technical publications are now prepared.
3. A third group comprises a great mass of teachers for whom research must be interpreted.
4. The fourth group consists of teacher educators who must keep abreast of the times in their important task in the education of prospective teachers.
5. The fifth group consists of professionals, groups closely related to or allied with education. The activities of this group mesh in with education. In this group is an increasing number of psychologists, pediatricians, recreation workers, social workers, and others.
6. The sixth group consists of members of boards of education, trustees of educational institutions, legislators, mayors, in other words, that large group of the lay public to whom education must look for support, finances, programs, policies.
7. The seventh group consists of parents and the general public who, after all, may appropriately be considered as the large consuming group, altho, of course, we must consider the children themselves as the ultimate consumers in education."

An examination of Dr. McKibben's report indicates that 73 studies were made in eight categories (the number of studies in each is shown in the parenthesis) including Curriculum (19), Teaching Procedures (12), Predictions of Achievement (8), Status of High School Science Teaching (10), Teacher Training (9), Science Interests of Pupils (4), and Miscellaneous Studies (6). What are the implications of these

[1] The Role of Research in Educational Progress, Report of the A.E.R.A. 1937, pp. 56–61.

categories of studies for each of the consumer groups in Dr. Bristow's classification? Let us take his first group of technically trained research people who are actually engaged in research studies. It is very likely that they would find very little in the way of new techniques, significant discoveries, or even suggestions for new lines of research. They would probably criticize many of the studies as being superficial in their conception and not rigid enough in their use of evaluative and statistical techniques. The second group of administrators and supervisors would study the reports on curriculum teaching procedures, predictions of achievement, in fact all of the 8 categories. This group is in fact the largest consumer of technical publications. To many of them falls the responsibility of attempting to apply the findings and recommendations of research.

Teacher educators would find many inplications in studies on teaching procedures, status of teaching, teacher training, and curriculum. The fifth group, including psychologists and social workers, would be deeply interested in the studies of talented children and in predictions of achievement. It is not my purpose, in this paper, to analyze the implications of each category of studies for each of the listed consumer groups. However, such analysis is likely to yield useful insights regarding the advisability of a planned pattern of research.

If we are to make science education research effective in meeting our needs—and by needs we mean those of society and our democratic form of government, we must implicate the sixth and seventh groups of Dr. Bristow's list of science consumers in the products of our research. In fact it may be advisable to use market research techniques wherein the knowledge, experience, and suggestions of the consumer are harnessed in the effort to attain a correct decision toward action. The sixth group consists of legislators and government officials to whom we must look for support, finances, programs and policies. The seventh group consists of parents and the public. Most of our science education research in the past has not been focused or directed toward a major goal. It has consisted of projects conducted for gathering higher degrees, studies of investigators attached to institutions and universities, and investigations which grew from local needs and interests. The results have been fragmentary and variegated and have not contributed toward the implementation of the research findings in connection with major movements or trends in science education.

The patterning of research raises the question of freedom for the research worker to study in any area he may wish—without strings attached. Research in science education like any educational research, is oriented toward social purposes and in this respect is different from pure, disinterested research. The science education researcher, unlike

the pure scientist who is seeking to establish a new truth or fact, works in applied research. The education research worker searches for new applications and relationships in the fields of motives, methods, materials, pupils, teachers, traits, facilities, and many other research variables. These vary widely in any given locale and consequently the findings are seldom applicable to broad situations. Working in a large project or pattern of research the research worker would still be free to use his best talents and initiative and in addition would be contributing toward a larger and very likely, a more important goal.

It is very encouraging to note that the number of research studies has increased in 1957 and 1958. Most of the studies will have little or no influence on the future development of secondary science education. This is due in part to the fragmentary nature of many of the reports, in part to the limited samplings investigated in terms of distributions and traits studied, and in part to the highly qualified and ambivalent conclusions reported. The latter was due in most cases to the difficulty of isolating the critical factor from the large number of variables involved in most studies, particularly those related to teaching methods.

Of the curriculum studies reported the most significant by far this year, and in many years for that matter, is that of the Physical Science Study Committee begun in 1956—well before Sputnik 1. The PSSC, in alphabetic nomenclature, not only developed a curriculum geared to physics of the mid-twentieth century but it prepared a complete implementing apparatus for it—including a text, laboratory exercises, films, a science library, a teacher's manual, teacher training materials, utilization and try-out on 12,500 pupils in 300 schools, and an evaluation program. This tremendous project is a fine example of planned, patterned research involving hundreds of people of all skills and talents—from Nobel Prize winners to cartoonists. A total of $1,695,000 was budgeted for the project with grants from the National Science Foundation, Ford Foundation, Fund for the Advancement of Education, and the Sloan Foundation. This is an example of what can be done with proper planning by means of governmental and philanthropic subsidies in the way of planned, patterned, and coordinated research—by gaining the support of the proper consumer groups mentioned earlier.

Studies related to teaching procedures included five investigations regarding visual aids. Television is being used more widely to bring outstanding teachers into the classroom. The fear that teachers will be replaced by electron tubes has been laid to rest. However, many studies—some not yet reported—are in progress in the area of tele-

vision instruction. Several fine studies involving thinking and reasoning were reported. Missing, however, are searching studies involving the psychology of learning. These are difficult, long, and expensive and should be supported by grants-in-aid. Two of the studies of teaching procedures were of doubtful validity.

Studies of talented children became very important in the explosive opening of the space age. Survival in the satellite race with Russia makes it imperative that we devise means to identify the gifted child at an early age, teach him up to his full potential, and give him opportunities to flourish as a thinker. The studies reported by Dr. McKibben were mainly surveys of the numbers of pupils studying science, materials usable by gifted students, and means of enrichment. Acceptable science aptitude tests to discover the potential of gifted children are still lacking.

Studies of status are important from an administrative as well as historical standpoint. Data on science registration, teacher preparation, and teachers' salaries were included in the 10 studies reported by Dr. McKibben. No clear pattern emerges from the reports from different states (Iowa, Louisiana, Kentucky, etc.) as local conditions vary. Small schools offer fewer courses in elective science, have teachers with inferior training, and poorer equipment. Are these not all effects of the poor salaries paid by smaller communities? The data reveals an old condition that cries out for correction. Would that the proper research consumer group mentioned earlier could act on the findings!

Teacher training studies in science education reveal that many teachers are inadequately prepared in terms of science courses, that most teachers' programs require them to have adequacy in teaching more than one science, that many institutions are not quite certain as to what preparation science teachers should have. The need for greater concentration in the physical and biological sciences poses a great problem. Where will adequately prepared teachers be obtained? This is particularly serious in science because industrial and engineering positions pay more and draw off the best prepared candidates for teaching. Will communities pay the necessary price to attract the skilled, professional science teacher? This is but a small price to pay in the struggle for scientific survival.

Studies related to science interests of pupils seem to indicate that better students consider science as a possible vocational future. Most pupils prefer the glamour of science through movies and television but shun the difficult work and comparatively poor financial reward it offers. Science is respected by youngsters as an institution but only the brighter ones respect the scientist as a real person or science as a

vocation. What can be done to make science attractive to the able student who lacks interest in science?

In conclusion, the 73 studies reported by Dr. McKibben represent an increase in research activity in secondary-school science education research. Some of the studies did not show real research quality in their sampling, measurement, and statistical treatment. There is a need for planned, patterned research similar to that of the Physical Science Study Committee. Research should consider the ultimate consumer in regard to the problems it seeks to solve and the manner in which it will report it. There are many urgent problems in need of concentrated and broad-front study. For example, what can be done to find our best science students and train them properly for creative work in science. Last but not least, we must find a way to convince the people that this is very important and that they must be willing to pay the cost.

Review of Research in College-Level Science Education

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The sixty or more titles which appeared in the literature during the period between July, 1957 and July, 1958, include a wide variety of investigations in the general field of college level science education. The fields may be broken up into the following categories:

1. Contributions from psychology
2. Kinds of courses and their contents
3. Characteristics of students
4. Teaching methods
5. Training of elementary and secondary level science teachers
6. Contributions in the realm of philosophy
7. Miscellaneous

Psychological studies emphasize or reemphasize such points of view as "the student must be put in an environment in which he will not only be exposed to the objects of knowledge, but will, in addition, actually desire and want to learn these objects," "Lack of problem-solving skills is the cause or reason for many cognitive errors," and "Students faced with problem-solving situations become less effective after failure in such situations." A whole-part approach seems to be consistent for most individuals facing problem-solving situations, but individuals differ in the flexibility-rigidity factor as they are confronted with situations of different structures.

While engaged in concept learning, learners forced to search for the

correct response after feed-back of their incorrect answers are more successful than those who are dependent upon a teacher for the correct answer. Intention to learn does not significantly facilitate retention of learned material although it does enhance original learning. Study habits, primarily reading, predict improvement better than any single variable, whereas verbal intelligence is likely to be inversely related to improvement.

Additional studies explore such things as the relationship between creative responses and working time and instructions, approaches to the learning process, transfer of learning, and many of the other questions traditionally involved in educational psychology.

Investigations of course content continue to seek courses adequate for general education purposes as well as toward improving the usual specialized courses in science. Attempts are being made to put the history of science into its true perspective, in fact, there is considerable groping for a central integrating theme around which general education and specialized introductory science courses may be organized. Many investigators are questioning how course content can be streamlined or otherwise modified so as to permit higher level instruction at each grade level.

Studies dealing with the characteristics of students are aimed toward identifying those characteristics most likely to be favorably related to success in the sciences. This reflects the science-student recruitment problem as well as the need for reducing the casualty rate among students already enrolled. Competency in mathematics continues to share a major responsibility for success of beginning students in science. Studies in methodology continue to emphasize the motivational benefits which seem to derive from experimentation in methodology. Few studies, however, reveal significant differences when one type of procedure is compared with another. Some very promising studies suggest that audio-visual aids, particularly television and motion pictures, are gaining in value as their producers develop new and better ways of incorporating problem-solving and other higher level intellectual processes.

In the area of elementary and secondary school science teacher training, the long-time dearth of definitive studies continues. Some attention is being given, however, to acquainting teachers in training with the resources available for enriching science teaching. There is a great need for college level science instructors to investigate the relationship between the success of students in their courses and the success of their graduates in the teaching field.

Writers from the field of philosophy emphasize the need to broaden the scope of training for specialists, to point the way to more social

wisdom, to keep scientific concepts and methods intelligible in our culture, and to cause traditionalists to be aware of change and progression while devotees of progress remain equally sensitive to traditions. Theology, science, and mathematics continue to arouse study not only from the point of view of integrating, but also of clarifying their individual functions.

Additional studies cutting across one or more of the above categories investigate such things as a comparison of the knowledges of physical science with those of biological science of college students, the development of attitudes concurrent with enrollment in science courses, and science and science-fiction.

No summary of research studies dealing with college level science will be complete without mentioning the many creative and inventive efforts being made to prepare textual material, laboratory exercises, classroom demonstrations, and other materials and equipment holding promise of improving efficiency of instruction.

Implications of the Findings of Research in College-Level Science Education

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Hans Selye (1), in what must have been a most delightful after-dinner talk, discerned in basic research three fundamental qualities: it must be true, it must be generalizable, and it must be surprising. When we examine the research in science education over the last year, we find that while it is true, like all research in the behavioral sciences, we shall have a most difficult task convincing a college audience that there are surprising discoveries or even generalizable ones. And herein lies the major difficulty in discussing implications of research in science education. We find ourselves using modals: What the implications *could be* or what the implications *should be*. We are chagrined perhaps by the realization that what the implications *will be* will almost certainly be several rungs below the *could be* and even more below the *should be*.

Aside from the surprising and generalizable elements, research in science education to be effective must eventually lead to changes in performance. The intense conservatism displayed by most teachers—and science teachers are no exception—towards their own teaching methods and procedures is almost unbelievable. There are those who insist that little can be done of value in this area; opinions bolstered by statements such as the classroom is

"an enormously complicated social situation and that it is impossible to generalize about the curriculum because any apparent learning is influenced by a great many factors unknown to (and some unknowable by) the researcher." (2)

Or in discussing the Brown University experiment in chemical education.

"Last year we endeavored to find out whether or not our curriculum was successful. *There seems to be no objective way to do this.*" Italics mine. (3)

Types of Studies

In spite of the pessimism which might be engendered by such statements as have been quoted, the many studies of science education attest to a faith in the improvability of our education in science if not in its perfectability. My classification of these studies distributes them into seven categories,

1. Improved or novel methods of presenting topics: new ideas, new experiments, or new materials.
2. New and improved courses and programs.
3. Studies of texts and suggestions for texts or syllabi.
4. Testing and evaluating.
5. Characteristics of science students and scientists.
6. Characterizing and presenting the scientific method.
7. Defining and stimulating creativity.

It is my opinion, based upon an informal poll, that college teachers pay attention to topics in their reading approximately in the order listed. On the other hand when commissions make recommendations, they imply at least that the only definition of research in education they honor is "research is simply a form of critical reflection upon experience." Thus two of the most important recent reports on physics teaching had this to say. The first, Improving the Quality and Effectiveness of Introductory Physics Courses (1957), has the statement,

"Each participant was asked, in advance of the conference, to prepare a short statement *outlining his views* on introductory physics courses, the way in which they fail to meet present needs, and how they might be improved." Italics mine. (4)

One might have inquired what studies have delineated present needs or what studies have been consulted relative to the shortcomings of present courses.

The second report, The Role of Physics in Engineering Education, introduces section II. Physics As It Is Now Taught, with

"As was mentioned in the foreword, the members of the Committee are convinced that a report of this kind to be meaningful must be based upon firsthand information gathered through actual visits to engineering institutions and on-the-spot discussions." (5)

Are studies so ephemeral and unreliable that they need not be mentioned?

Thus one feels that much of the good work in the categories 1 to 7 ahead is not having as pervasive an influence as it deserves. Unfortunately I cannot here emphasize the *could* and *should* of the implications. Rather I shall single out two categories for more extended discussion.

In my opinion, the two areas of science education which have not received their proper attention and which have the most far-reaching implications for the science programs of our colleges are category 5, Characteristics of science students, and category 7, Defining and stimulating creativity. For if the great agitation in education since October 4, 1957 has done nothing else, it has revealed that our sources of difficulty reside not in the numbers of our students but in what they carry away from our schools and colleges.

The best sources of information concerning our students are not only the conventional journals but also the journals devoted to discussing the medical student. Inasmuch as every medical student spends at least two years in college, this is not surprising. Unfortunately since only 2% of all college graduates enter the practice of medicine, this group represents a small and probably not too representative a sample. The important feature is that the methods of study and the over-all conclusions with respect to these students parallel those for students in all the sciences since they are drawn from the same population and have essentially the same median intelligence test scores.

Median intelligence test scores of graduate students:

Physics and mathematics	131
Chemistry	129
Medicine	127
Engineering	126
Biological sciences	126

The factors which in my opinion are most significant are called in this study (6), The Nonintellectual Characteristics of Applicants. The paper which I should like to direct especial attention to within this section is that by Funkenstein (7). The data in this study were organized under three headings, the first two of which are

1. The students
   - A. Social factors
   - B. Basic personality factors
   - C. Factors within the personality
2. The school
   - A. Cultural values

B. Students' attitudes
C. Teaching techniques

In the studies of students, Funkenstein reported on the extremes in a certain personality assessment test, the S (stereopaths) and the N (non-stereopaths). The S-like are characterized by rigidity, certainty, little conscious guilt or anxiety, little introspection, little awareness of psychological factors, and strong defenses. The N-like have extreme flexibility, many doubts, conscious guilt and anxiety, much introspection, marked awareness of psychological factors, and moderate defenses. Quoting Funkenstein on these extremes (8):

He (Wispe) divided teaching techniques into two types: *teacher-centered* and *pupil-centered*. In teacher-centered teaching the lecture method was used, the content of the course was highly organized, and the teacher was extremely authoritative. In pupil-centered teaching the discussion method was used, the content of the course was loosely organized, and the teacher was extremely permissive. Wispe found that most students learned equally well in both sections, with the poorer students doing better in the teacher-centered classes. However, at the two ends of the personality continuum, the learning of the individual student was related to the interaction between the personality type and the teaching method. The very extrapunitive (S-like) students learned best in the pupil-centered classes and poorest in the teacher-centered classes. In the latter classes they expressed a great deal of resentment and hostility. These same students when placed in a pupil-centered class, able to proceed on their own and express their feelings, learned much more, probably because they were not in conflict with the teacher.

The ultimate goal is not just understanding the science student and his relation to his school and environment but in using that understanding to do more effective and rewarding teaching. Hence we must confront the formidable problem of defining and stimulating creativity in our students, our final category. Bartunek (9) considers this dimension of our teaching when he writes

"Physics is much more than a mere accumulation of knowledge. It is a human creative activity. If teaching stresses only the first of these aspects, the study of physics will strike students as inert and dry labor rather than as the challenging and rewarding experience it can be."

And Brown (10) underscores it when he concludes

". . . laboratory education at the University level must have as its goal the teaching of the scientific point of view and the intellectual challenge of the experimental method, rather than the training of students in particular or specific techniques or in carrying out particular experiments, since the details of these are so obviously lost in a very short span of time."

McCrory (11) in discussing creativity in industrial and government laboratories suggested that it may be enhanced by attention to several important factors. Paraphrasing them for the college, we list selecting effective teaching personnel, providing a stimulating teaching environment, and assuring adequate financial support for promis-

ing developments. On the stimulation of individual creativity, Walkup (12) maintains that through attention to the relative factors each of us can enhance his "creativity quotient."

In placing emphasis upon the student and creativity in this brief survey of implications, I am expressing the belief that no matter how clever our demonstrations, how well-organized our laboratories, or how varied our testing, the ultimate criterion is what does the student do. For in science as in all other education, we do not teach, we stimulate the student to learn, to develop enthusiasm and a keen interest in learning even when learning involves intellectual drudgery as in theoretical mechanics. These are ancient concepts, perhaps, but the research on science education assures us that they are still valid.

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Summary

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Before a proper summary of the research reported and implications presented may be made, it is appropriate that the complex nature of the sequence and pattern for reporting science education research be, again, identified. The sequence, and the emerging pattern, includes this initial presentation at the Annual Joint Conference of the Science Teaching Societies affiliated with the AAAS. School Science and Mathematics has consistently published this report since its inception by George and Jacqueline Mallinson at the California meet-

ing of AAAS. The reports have been extended and definitely reported at the annual NARST meetings, and formally published as the Annual Review of Research in Science Education in the December issue of *Science Education*. Recently, the Office of Education in HEW has pooled the material and published their *Analysis of Research in the Teaching of Science* as an additional feature in the sequence-pattern. This intimate cooperative interrelation provides science educators, at all levels, with a process which is unique in the cataloguing, analysis, and reporting of research. The process has no counterpart in American Educational Research.

Our previous reviews and summaries of the research for a particular year have sometimes been forced to operate within a negative field, for much of the research which was reported and reviewed was of a "low level" calibre. Perhaps the most notable and striking feature of the research reported here is that it is, without doubt, of very high character. This applies both to the increased quantity of research which was dealt with as well as its generally higher quality of design and treatment of the data.

Another striking feature of the research reported is the scholarly and scientific operations of the "reviewers" and the extent to which the "implications" presentations represented serious and contemplative reaction to the research reviewed. It is not possible for me to add to such presentations and analyses without, at the same time, detracting from their import.

Despite these striking considerations, and because there is an apparent resurgence of scholarly concern for increased scientific investigation of science teaching, there are certain areas of investigation to which science educators have not yet turned their attention, or to which we have paid relatively too little attention. Obviously a conspicuous deficit lies in our sophistication in use of the mass media. Further, there are the obvious dearths in development of new and more effective techniques for presenting academic subject matter; for models and designs built on holistic and field theoretical conceptual bases; for study of the implications, if any, of organismic learning theory and motivational psychology to science teaching; and studies of the usefulness of group dynamics for structuring the teacher-learning situation. In addition, there are the conspicuous lacks in longitudinal studies, for too many of our studies continue to reside in inadequate space-time continua, often of no more than four to eight week durations for some of the simpler experimental and synthetic studies.

The major point stressed here is that much of our research continues to deal with *problems of simplicity*. That is, it is experimental

and synthetic in character, dealing with one or two variables, change in one of which is assumed to cause change in the other. The somewhat simple design and theory characteristic of this conventional scientific research was developed during the 19th century and has extended into the mid-twentieth century. Research on *problems of simplicity* has yielded a vast quantity of data which, atomistic and mechanistic as it is or was, is responsible for much of our current progress. Respectable and responsible as such research has become, nevertheless some research workers have moved into work on *problems of disorganized complexity* through use of the statistical dynamics of probability and game theory, enabling them to deal with millions of variables. Such research, confined as it is to whole systems possessing orderly and analyzable properties, applies with increasing precision as the number of variables increases. Science education research on problems of disorganized complexity has yet to fulfill its role and function.

Increasingly, however, it is clear that many of the problems associated with the teaching of science lie in a middle area, and solution of these problems or their study is too complicated to be dealt with by use of the two-factor variable controlled experiment or synthetic research. Likewise these problems cannot be adequately dealt with by use of the statistical techniques and designs useful in describing average behaviors. This is the area of *problems of organized complexity*, a somewhat virgin and unexploited, unexplored territory in science education research. This is research which often demands a "mixed-team" or "inter or multi-disciplinary" approach. Such analyses would involve the simultaneous dealing with the intervening, the independent, and the dependent variables. Additionally, such research would demand a kind of "re-tooling" of our research designs and models, and increased use of the new electronic computing devices which make it possible for us to deal with data in a manner which was previously too complicated and time consuming to even consider.

The extent to which research in the teaching of science continues to operate "outside" the middle of the twentieth century and in the domain of the 19th and early 20th century is, in itself, a research concern which needs some consideration by our people. Despite such research findings, one can, even now, postulate that much science education research today improperly or completely ignores the advances in research design and models, and refuses to use the scientific and technological developments which are now available to a research worker in the electronic computing devices.

Continental Classroom: an Experiment in Educational Television

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Continental Classroom is the first college credit course televised on a nation-wide basis. This course consists of a series of lecture presentations on "Physics for the Atomic Age" conducted by Dr. Harvey E. White, Professor of Physics and Vice-Chairman of the Physics Department at the University of California.

The televised lectures are given and video taped approximately two weeks before the actual telecast. The lessons are then telecast on the scheduled lesson day from 6:30 A.M. to 7:00 A.M. each weekday morning. The first "semester" work consists of 80 lessons which represent a review of first year college physics. The second "semester" work consists of 80 lessons on the topics of atomic and nuclear physics. The avowed purpose of these 160 lessons is to bring high school teachers up to date on recent developments in physics and thereby create a general upgrading of high school science teaching.

The Continental Classroom program is co-sponsored by The American Association of Colleges for Teacher Education and The National Broadcasting Company. It is supported both by foundation funds and funds from industry.

The first news of the Continental Classroom project burst upon colleges and universities in September 1958 with a perturbing suddenness. Scarcely a month's time existed for these institutions to solve the numerous problems which beset a new course offering.

A great deal of interdepartmental cooperation was necessary in order for a college or university to become an effective participating member of this program by the beginning date of October 6, 1958. This is a report of the problems encountered by Western Michigan University and the manner in which the Continental Classroom course was finally implemented.

In early September 1958 the author was appointed as W.M.U.'s TV coordinator charged with the responsibility of (1) determining which students were qualified to enroll, (2) holding bi-weekly meetings with the students, (3) determining the final grades, and last, but not least, (4) watching 160 telecasts at 6:30 A.M. The salary for this work was established by the Division of Field Services of Western Michigan University to be $1,000 for the year. Various problems which confronted the coordinator and the resultant decisions are given below:

Problem: Should either graduate or undergraduate credit be offered for this course and if so, how much.

Decision: W.M.U. would offer both graduate credit and undergraduate credit in teacher education degrees for both the first semester (general physics review) and the second semester (atomic and nuclear physics).

Problem: Where should the group meetings be held.
Decision: The first meeting was to be held on W.M.U.'s campus. Other future meeting places might be chosen if 20 or more students were clustered in a particular region. (Actually, the center of gravity of the enrolled students was in the Kalamazoo vicinity so the successive meetings were held in Kalamazoo on W.M.U.'s campus.)

Problem: On what day and at what time should the group meetings be held.
Decision: The group meetings were held on Saturdays. It was felt that people would be willing and able to drive farther for a Saturday class than for an evening class. Since this course was designed primarily for teachers it was felt that teachers would have fewer obligation conflicts on a Saturday commitment. The first meeting was arbitrarily set for 8:30 A.M. with expectations of altering the meeting time to accommodate class desires. (A vote at the first meeting was overwhelmingly in favor of retaining the 8:30 A.M. time.)

Problem: What prerequisites should be required.
Decision: Prerequisites of one year of college physics and one year of college mathematics were highly recommended. It was felt, however, that if this was to be truly an upgrading of science teaching, an effort should be made to accommodate the student without the prerequisites who might nevertheless be in need of the course. The TV coordinator admitted several such students with the proviso that they would revert back to an audit status if their work was not satisfactory.

Problem: What method or methods should be used in so short a time to bring the news of the TV course to the attention of potential students.
Decision: It was intended that three main avenues of advertising would be used to get pertinent information to prospective students. These were:

(a) the newspapers.
(b) the TV station WOOD-TV which was to carry the Continental Classroom program.
(c) The dissemination among the high school principals and superintendents of a brochure which contained pertinent facts about the course.

Unfortunately, the W.M.U. publicity director was stymied in getting news articles into the local paper because the newspaper was reluctant to advertise another medium of advertising.

Strangely enough, oral promises of advertising by station WOOD-TV did not materialize.

The main medium of advertising, therefore, was the dissemination of the brochures to the superintendents. Regrettably, these occasionally became trapped on the superintendents' desks and did not filter down to the teachers until the course had started. (W.M.U. received and accepted enrollments for a month after the course started from people who "had just heard about the course.")

Problem: How many textbooks should be ordered.
Decision: It was difficult to anticipate the number of people in the several county area surrounding W.M.U. (Kalamazoo) and the TV station (Grand Rapids) who would enroll for credit. If the TV coordinator greatly over ordered on books, the campus store would not be happy about returning them. If the texts were underordered, some of the students might be without texts. Further, if the demand was larger than the publisher anticipated, some students might be without texts all semester.

It was finally decided to lean in the direction of overordering. One hundred texts were ordered. Various educated guesses on enrollment were 10—20—50—? It was the question mark which was perturbing. Initial enrollment actually was 40 credit plus 3 audit.

Problem: Publication of an advertising brochure.

Decision: It was vital that the brochure be disseminated with the utmost of speed to permit time for it to filter into the hands of prospective students. Less than a month existed to reach decisions on credit and meeting place; to get this information printed into the brochure; to get the brochures mailed to superintendents; and to permit time for the brochures to get to the students. This frantic hustling could have been eased considerably if the cooperating colleges had been provided with a few more weeks advance notice that such a TV course might even be possible.

Problem: How should the biweekly meetings be conducted in order to:
(a) best serve the student needs.
(b) evaluate student progress.
(c) determine if the student is watching the TV program.

Decision: After the first organizational meeting, the succeeding meetings were conducted in the following manner: At 8:30 A.M. coffee and cookies were served. This refreshment was available to the students throughout the class period. Some class members had to rise at 4:00 A.M. to drive over a hundred miles to the Kalamazoo class. These people especially welcomed the warmth of coffee on cold days. This feature was prepared by the coordinator and financed by the students.

The first hour of the class meeting was devoted to: (a) discussion of certain TV lessons, (b) supplementary demonstrations, and (c) solution of assigned textbook problems. The need for help seemed to be primarily for problem solving assistance.

The second class hour was devoted to an examination over the previous two weeks telecasts and problem assignments. Simple key questions were injected into these examinations which were related to the telecasts. These questions were easy for the viewer and could not sensibly be answered by the non-viewer.

The final grades for the students were determined on the basis of the summation of the scores earned on 5 one-hour examinations, one two-hour mid-term, and one two-hour final examination. The final grades earned may be summarized as follows:

TABLE I

GRADE DISTRIBUTION

D	C−	C	C+	B−	B	B+	A−	A
2	1	4	2	3	9	3	2	3

In general the quality of students in this TV class was superior to the quality of students in the average extension class.

Problem: Icy road conditions sometimes prevented students from attending class.

Decision: Recognizing that sometimes icy road conditions made travel to class extremely hazardous, the coordinator established a policy of permitting the students the privilege of making up the examinations from two missed meetings. A third missed examination would be graded at ½ value.

Problem: How can extra help be supplied to the students without meeting every Saturday.

Decision: It was felt that if the class met (optionally) on alternate Saturdays, the far-travelling students would either feel coerced to attend or would feel that they were "missing something" by not attending. To provide additional assistance the students were invited to write the coordinator in between the biweekly meetings about questions on the TV lectures or about assigned problems. Many questions were answered by correspondence in this way.

The academic backgrounds of the students are listed in Table II.

TABLE II

ACADEMIC BACKGROUNDS IN SCIENCE AND FINAL GRADES

Student	Background	Final Grade
A	Physics minor Math minor (Chem. minor)	A
B	Physics Math minor (Chem. major)	A
C	Math major, Physics 1941 P.G. Naval arch.+Engineering	A
D	½ Physics, Alg. This student is attending WMU on the Fox Physics Scholarship.	A−
E	Physics minor Math minor	A−
F	Physics major Math major	B+
G	Physics major Math minor	B+
H	(M.S. in Chem) Physics, Math through Calc.	B+
I	Physics, Math minor	B
J	Physical Science Course Math minor	B
K	Physics minor Math major	B
L	Physics, Alg., Trig., Calc.	B
M	Physics	B
N	Physics, Math minor (Chem. minor)	B

Student	Background	Final Grade
O	Radio Ham	B
P	Physics minor Math major	B
Q	Physics minor Math minor (Chem. major)	B−
R	Physics, Chem. Math through Calc.	B−
S	Physics Minor Math through Calc.	B−
T	Physics minor (Chem. major)	C+
U	Math major Science minor	C+
V	Physics minor Math minor (Chem. major)	C
W	M.A.E., Physics Chem. minor	C
X	Physics 1947, Trig.	C
Y	B.S. in Physics Math through Calc.	C
Z	2 year Physics Math minor	C
AA	Physics, Alg. (Chem. minor) (Biology minor)	C−
BB	1 year Physics Math major (Chem. minor)	D
CC	Physics 1920 (Chem. major)	D
DD	M.A. degree Physics, Alg.	Audit
EE	Alg., Trig., Navy Radar	Audit

At the last meeting the class was asked to write out responses to evaluation questions. They were assured that their final grade was in no way dependent on their answers. The questions and representative or significant answers are given:

Question: Please compare and contrast education by television with education in a regular classroom. List comparative good points and bad points of each.

Response:

Good	*Bad*
Very best of instructors	Faulty reception
Very best of equipment	Depends on TV receiver
Close-up views	Cannot ask questions
Can tape record the lecture	Lack of student-instructor rapport
No delay while instructor answers a question you already know the answer to.	Color demonstrations (in black and white TV) are not well visualized
Can go to school at home	Lack of day to day personal contact
I can concentrate at 6:30, no other noise at that time.	Difficult to take notes
Allows person working full time to take course	No chance for repetition (by the instructor)
Instructor better prepared	Home distractions
Can see demonstrations better	Some instructors tried to cover too much in too little time.
Others besides class members watch and become more sympathetic toward science	Tendency to put off assigned work.
More uniformity in teaching	Lack of student to student discussions outside of class
The instructor is not interrupted by other students	
Excellent teaching techniques	Lecturer cannot tell how fast students are taking notes
Convenient	
Cheaper—less transportation costs.	

Question: Your instructor has chosen to give bi-weekly examinations as a means of monitoring
(a) student progress toward learning course material
(b) TV viewing attendance
Is there another method or methods which you think would be a more satisfactory means of monitoring these two items?

Response:

Do not want to be monitored by examination.	Present method Satisfactory
0	*28*

No. Testing is the best way. Discussion periods don't help me as much as a quiz.
No. This tells who goofed. He reaps what he sows.
Perhaps a few problems to be done and handed in at the next meeting.
The first method was achieved much more so than the second but like most students, I can't think of a better method.
I think this method is fine. I like the fact that one can miss one or two meetings during the semester and not harm his grade.

This is the best method. They could be more difficult; thereby requiring more study.

Question: What features would you like to see added to the bi-weekly Saturday meetings? What items would you like to see changed or deleted?

Responses: Regular time for explanations plus definite time limit for actual tests.
This would facilitate transportation problems for some.
More discussion.
Think we could use more time.
Different problems with different variables.
Less frequent testing.
More opportunity for individuals to engage in experiments.
A class farther north.
A short lecture reviewing the material covered with some specific examples such as problems.
Information dealing with construction of demonstration equipment.
More demonstrations.
I like the meeting as is.
None.
Further discussion of the TV presentations.
I would prefer to meet every week.
I think the bi-weekly meetings are alright the way they are.
I would like to see the meetings held in other convenient centers, but I realize the problem. Some of us drive 100 miles to get here and it gets old in a hurry.

Question: Do you think that a person who had no previous physics courses would have gained more from White's TV course or from a regular college physics course? Please explain.

Response:

TV Best	*Same*	*College Best*
3	1	23

With no previous experience in physics, a student would get more from the regular college physics course. This would provide the student with adequate teacher guidance, plus added *laboratory* experience. Each student seems to have different areas of "ignorance"—and it takes the wise guidance of a teacher to provide the extra "reading," "drill" and study for each individual's needs.

Question: Do you feel that you have learned more from White's TV course than you would have from a regular college physics course?

Response:

TV Best	*Same*	*College Best*
10	2	16

Lectures better coordinated.
Use of the split screen permitted close up of several meters simultaneously.
Ability of the instructor to concentrate on one preparation—and do it well.
The better instructors can teach far more people than ordinary.
Observation is uniquely excellent for all.
Permits persons who travel the opportunity to acquire information.
Guest lectures
Gives more people an opportunity to take the course.

Question: Please make any other general comments about learning by televison or the content and operation of this particular course.

Response: Guest speakers generally don't give time for notes.

Possibility of two showings daily if such programs continue (morning and night).

I was glad to be a part of this first course and feel it was worth while enough to continue.

Complete descriptions, diagrams, construction and method of use of more complex demonstration equipment would be helpful if made available to those desiring such information.

I think the course has been a real asset in my teaching of physics. I have gained much knowledge and new techniques from the course. I believe I am a better teacher for having taken it.

I think you helped us very much by allowing us to write in for the solutions of problems.

I thought everything was run very well, possibly from not knowing any better, but I enjoyed it.

I think that learning by TV is excellent in expanding a persons knowledge in a particular field. But, I do not think that it is good for the basic work in the field.

Though I feel one can gain more from a regular college course, I think education TV is a wonderful innovation.

I hope it is continued and expanded. I think everyone involved in producing the TV program did a fine job this semester.

Hope the use of TV is greatly expanded.

I think White has stressed topics which are lightly covered in ordinary college physics. Also he gives a different approach to his topics.

More time (and possible use of text) on stiff test questions.

I have enjoyed the course and have learned quite a bit from it. I would like to see some emphasis placed on how to do things in teaching as well as the subject matter itself. If you don't get it across it doesn't help much to know all about it.

Station interference occasionally disrupts the program for me as I get it in a fringe area.

Thank you for a fine course. The atmosphere was friendly, courteous, and thoughtful. I sincerely enjoyed the course.

I think the medium has been very effectively used and that we should do what we can to support and encourage it.

I enjoyed this TV course very much. It has been of great value.

Too much material is covered in too short a time.

I for one would not have been able to take a course like this if it had not been presented on TV.

The course was taught very well by all who participated in it. I think Dr. White explains things better and makes the contents easier to see than most guest speakers.

A fine use of the TV medium. Colleges should consider use of the medium in all phases of adult education.

As the W.M.U. coordinator for "Physics for the Atomic Age" the author has felt privileged to participate in the Continental Classroom venture. Listed below are related comments and convictions of the author pertaining to nationwide educational television.

1. The inability of the student to ask on-the-spot questions of the TV instructor about the lecture material is considered by the student to be the greatest deficiency of educational television.
2. It should not be expected that educational TV will economically solve the teacher shortage as we know it today.
3. The classroom teacher need not fear that television will replace his singular role. As in industry, supplementary innovations produce more jobs, not fewer.

4. Educational television, which may enter any home at the twist of a knob, is charged with considerable responsibility to attempt to decrease the public "egghead" stigma imposed on educated people.
5. One major defect of "Continental Classroom" pertains to the insufficient note-taking time provided.
   As a good instructor, Dr. White walks away from the blackboard to give his "students" a chance to copy the material. Unfortunately, the camera takes a quick close up look at the blackboard and then returns to Dr. White.
6. Guest speakers on Continental Classroom (including Nobel Prize winners) are of great cultural value. It is believed that this "contact" has led to the upgrading of high school teaching in more than just an academic sense.
7. Television does not provide as satisfactory a learning stiuation for the beginning student as the regular classroom. More advanced students may gain equally from both mediums.
8. Continental Classroom has been significantly successful in increasing the levels of science understanding of many teachers.
9. It is anticipated that a second year of Continental Classroom will be offered. The chosen topic will presumably be in the field of chemistry.

SOUNDS CAN PRODUCE PHYSIOLOGICAL RESPONSES

Sounds that you hear—both pleasant and unpleasant—produce complex physiological responses, including hormonal changes.

In an early investigation scientists have been able to demonstrate a measurable physiological response of an individual to a given piece of music that could be correlated with how the individual rated the piece as to the degree of pleasantness or unpleasantness.

The physiological measurement was the galvanic skin response, an important component of the lie detector test.

In more recent experiments there has been shown a relationship in animals between sound of a given frequency and intensity and production of corticosterone, one of the hormones produced in response to stress.

These results indicate that the auditory pathway is a complex one. The appreciation of sound is not just a matter of energy traveling from the ear to brain hearing centers for complex hormonal changes are also involved.

Unpleasant sounds may produce a hormonal picture characteristic of stress. Pleasant patterns of sound, such as music, may produce or maintain an organized hormonal situation.

Music that you do not understand appears to have no different physiological effect than silence. In other words, if you do not understand it, you may not perceive it as music.

RECORDER FOR "MOONQUAKES" SLATED FOR CONSTRUCTION

A recorder to detect earthquakes on the moon, then radio any information obtained to stations on earth will be built by scientists at Columbia University in New York and the California Institute of Technology.

Construction of the lunar seismograph, sponsored by the National Aeronautics and Space Administration, may cost about a million dollars. Aim of the project is to meet space, weight and acceleration conditions encountered during the instrument's rocket trip to the moon.

The Caltech and Columbia scientists will design, built and test either vertical or three-component lunar seismograph systems, or both. If the 10– to 20-pound instrument is successfully developed, NASA hopes to land it on the moon within five to six years.

Annual Convention of the CASMT

CONGRESS HOTEL
CHICAGO, ILLINOIS

THURSDAY, NOVEMBER 26–SATURDAY, NOVEMBER 28, 1959

Theme: "NEW SCIENCE AND NEW MATHEMATICS FOR A NEW ERA"

A series of general sessions will be held at the convention, beginning on Thursday evening. Among them will be the following:

Thursday evening, November 26, 7:30 P.M., Lincoln Room—
Dr. Glenn W. Giddings, General Electric Company:
"Science in our Times"

Friday morning, November 27, 9:00 A.M., Gold Room—
Dr. Alston S. Householder, Oak Ridge Laboratories:
"Life, Living and Livlihood"

Friday morning, November 27, 11:05 A.M.—
Mr. Jerrold Maben, Michigan State University:
"Traveling Science Teachers Program, Michigan State University"

Friday evening, November 27, 7:30–9:00 P.M.—
Dr. Hubert Alyea, Princeton University:
"Atomic Energy: Weapon for Peace"

Friday evening, November 27, 9:15 P.M.
Informal Reception

Saturday morning, November 28, 8:30–9:40 A.M.—
Joe Kennedy, Chairman:
Sessions of short presentations by members on Teaching Techniques

Saturday noon, November 28, 12:15 P.M.—2:00 P.M.—
Annual luncheon—Speaker: Dr. John Mayor, Director of Education, AAAS:
"1959 Science Education Leads the Way in Education"

The following special events will also be featured:

Friday afternoon, November 27—
The following tours will be available:

1. Standard Oil Refineries, Whiting, Indiana ($2.00)
2. Electromotive Division of General Motors, LaGrange, Illinois ($2.00)
3. Heliocopter Tour—Meigs to Midway to O'Hare Airports ($12.10)

Friday afternoon, November 27, 2:00–4:45 P.M.
Panel Discussions on Modern Curriculum Problems

Biological Sciences
Physical Sciences
Mathematics

(these discussions will cover all levels of instruction)

* * *

MAKE PLANS NOW TO ATTEND THE CONVENTION

Problem Department

Conducted by Margaret F. Willerding

San Diego State College, San Diego, Calif.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution or proposed problem sent the Editor should have the author's name introducing the problem or solution *as on the following pages.*

The editor of the Department desires to serve his readers by making it interesting and helpful to them. Address suggestions and problems to Margaret F. Willerding, San Diego State College, San Diego, Calif.

SOLUTIONS AND PROBLEMS

Note. Persons sending in solutions and submitting problems for solutions should observe the following instructions.

1. Solutions should be in typed form, double spaced.

2. Drawings in India ink should be on a separate page from the solution.

3. Give the solution to the problem which you propose if you have one and also the source and any known references to it.

4. In general when several solutions are correct, the one submitted in the best form will be used.

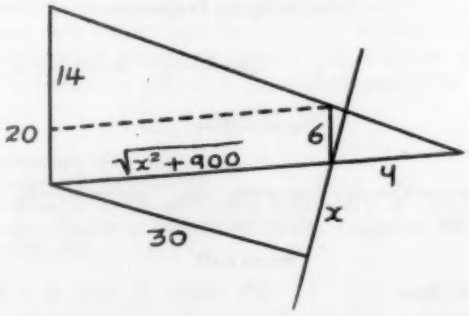
LATE SOLUTIONS

2669. *Lee H. Mitchell, Glencoe, Ill.*

2671. *Proposed by Wm. W. Johnson, Cleveland, Ohio.*

An electric light is suspended at a point 20 ft. above and 30 ft. to one side of the center line of a straight horizontal sidewalk. A man 6 ft. tall started from the point opposite the light and walked along the sidewalk at the rate of 4 ft. per sec. How far was he from his starting point when his shadow lengthened at the rate of one ft. per second?

Solution by C. W. Trigg, Los Angeles City College



As is evident from the figure,

$$y/6=\sqrt{x^2+900}/14$$

Differentiating and simplifying,

$$14\frac{dy}{dt}\sqrt{x^2+900}=6x\frac{dx}{dt}.$$

Then since $dy/dt=1$ and $dx/dt=4$,

$$7\sqrt{x^2+900}=12x$$
$$95x^2=49(900)$$
$$x=\frac{210}{\sqrt{95}}\doteq 21.546 \text{ ft.}$$

Solutions were also offered by Merrill Bernebey, Tougaloo, Miss.; W. R. Talbot, Jefferson City, Mo.; and Dale Woods, Pocatello, Idaho.

2672. *Proposed by Cecil B. Read, Wichita, Kans.*

Suppose a represents any of the digits from 1 to 9 in our ordinary decimal system. Clearly for $a=9$,

$$aaa<a^{aa}<a^{a^a}<a^{a^{a^a}}.$$

Determine other than by trial and error, the least value for a for which the inequality is true.

Solution by H. R. Leifer, Pittsburgh, Pa.

The inequality may be rewritten in the following form:

$$a^3<a^{a+1}<a^{a^2}<a^{a^a}.$$

Then $3<a+1<a^2<a^a$, and $a\geqq 3$. Thus the least value for a for which the inequality is true is 3.

Solutions were also offered by Armond W. Bear, Milwaukee, Wis.; Jack Goldberg, West Englewood, N. J.; Kenneth Ketelhohn, Milwaukee, Wis.; W. R. Talbot, Jefferson City, Mo.; C. W. Triggs, Los Angeles, Calif.; and Dale Woods, Pocatello, Idaho.

2673. *Proposed by C. W. Trigg, Los Angeles City College.*

Given:

$$M=(b-c)^3(b+c-2a)+(c-a)^3(c+a-2b)+(a-b)(a+b-2c).$$

Express M, (1) in factored form; (2) as the sum of three cubes; and (3) as the sum of two cubes.

Solution by the Proposer

(1) Let

$$a+b-2c=x, \qquad b+c-2a=y,$$

and

$$c+a-2b=z.$$

Then

$$x-z=3(b-c), \qquad y-x=3(c-a), \qquad z-y=3(a-b),$$

and

$$x+y+z=0.$$

Substituting, we have

$$M=\tfrac{1}{3}[y(x-z)^3+z(y-x)^3+x(z-y)^3]$$
$$=\tfrac{1}{3}[xy(x+y)+yz(y+z)+zx(z+x)-6xyz]$$
$$=-xyz=-(a+b-2c)(b+c-2a)(c+a-2b).$$

(2)

$$x^3+y^3+z^3-3xyz=(x+y+z)(x^2+y^2+z^2-xy-yz-zx)=0,$$

so

$$M=-xyz=-\tfrac{1}{3}(x^3+y^3+z^3)$$

$$=[(a+b-2c)/\sqrt[3]{-3}]^3+[(b+c-2a)/\sqrt[3]{-3}]^3+[(c+a-2b)/\sqrt[3]{-3}]^3.$$

(3)

$$M=2(a^3+b^3+c^3)-3(a^2b+ba^2+b^2c+bc^2+c^2a+ca^2)+12abc$$
$$=2(a^3+b^3+c^3)+3[-1+1+\omega+\omega^2](a^2b+ba^2+b^2c+bc^2+c^2a+ca^2)+12abc$$
$$=(a+\omega b+\omega^2c)^3+(a+\omega^2b+\omega c)^3,$$

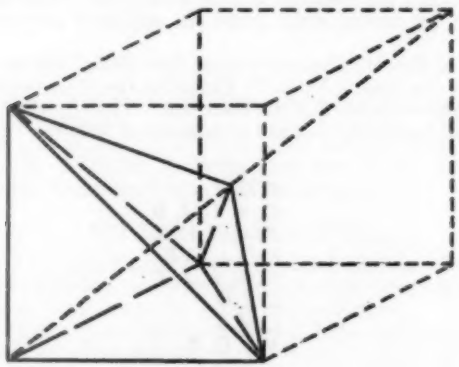
where ω and ω^2 are cube roots of unity and $1+\omega+\omega^2=0$.

A solution was also offered by W. R. Talobot, Jefferson City, Mo.

2674. *Proposed by John Nayler, Calgary, Alberta, Canada.*

Every edge of an aluminum cube of 3 in. side is beveled 1 in. by 1 in. at 45°. Calculate the volume of metal removed.

Solution by C. W. Trigg, Los Angeles City College



The 3 in. cube may be considered as composed of 27 unit cubes. The beveling process will convert each corner cube (as shown in the figure) into a double pyramid with an equilateral triangular common base with side $\sqrt{2}$ and a combined altitude $\frac{1}{2}\sqrt{3}$. Hence the volume of the double pyramid is

$$\tfrac{1}{3}[\tfrac{1}{2}\sqrt{2}\cdot\tfrac{1}{2}\sqrt{2}\sqrt{3}][\tfrac{1}{2}\sqrt{3}]$$

or $\frac{1}{4}$, so $\frac{3}{4}$ cubic inches are removed.

Each mid-edge cube will be bisected.

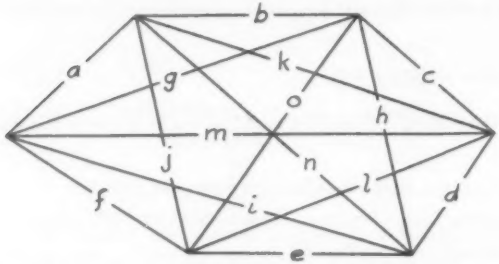
Therefore the volume of metal removed is $8(\frac{1}{4})+12(\frac{1}{2})$ or 12 cu. in.

Solutions were also offered by Merrill Barnebey, Tougaloo, Miss.; and W. R. Talbot, Jefferson City, Mo.

2675. *Proposed by J. B. Love, St. Davids, Pa.*

Given 6 points, no. 4 coplanar and no. 3 colinear. Connect all points to every other point and color the resulting line segments either black or red. Prove that for one of the triangles formed, all three segments forming the triangle are one color.

Solution by C. W. Trigg, Los Angeles City College



There will be $C(6,2)$ or 15 line segments which form $C(6,3)$ or 20 triangles. Such a configuration, which might result from the vertices of two skew tetrahedra with a common edge, can be projected onto a plane for the purpose of analysis. The plane can be chosen so that the projection is a hexagon and its diagonals.

Without loss of generality, any closed chain of six segments may be chosen for consideration of the possible arrangements of the two colors and of their implications. There are only eight essentially different arrangements of the two colors possible on the six-segment closed chain, where interchange of the two colors does not change the essential arrangement. Now, referring to the projection in the figure, let capital letters represent one color and lower case letters the other color.

If all segments of the chain have one color, then *abcdef*, and to avoid a triangle with three sides of the same color G, H, I must be the other color, but this gives a triangle with three sides GHI of the same color. The argument in abbreviated form for the eight essentially distinct arrangements follows:

If	*then*	*but*
abcdef	G, H, I	*GHI*
Abcdef	K, m, G, I, H	*GHI*
ABcdef	H, n, J, K, L	*JKL*
AbCdef	I, L, o, G, H	*GHI*
AbcDef	K, m, n, J, L	*JKL*
ABCdef	L, g, O	*CLO*
ABcDef	g, M, i	*fie*
AbCdEf, k	N, j, O, L	*CLO*
AbCdEf, K	m, L, o, j	*iob*

Thus for any assignment of black or red to the line segments at least one triangle will have sides all one color.

Solutions were also offered by J. C. Lanz, Palmyra, Pa.; W. R. Talbot, Jefferson City, Mo.; and the proposer.

EDITOR'S NOTE: Joe Kennedy, Bloomington, Ind., states that this problem is identical to problem E 1321 of the Elementary Problems and Solutions Section of the February 1959 issue of *The American Mathematical Monthly*.

2676. *Proposed by Brother Felix John, Philadelphia, Pa.*

Solve the equation

$$(x+1)^6-1344x=(x+1)^6.$$

Why does the equation have only five roots?

Solution by Mother Alphonsa Kohne, O.S.U., Arcadia, Missouri

$$(x+1)^6-1344x=(x-1)^6$$

$$(x+1)^6-(x-1)^6-1344x=0$$

$$[(x+1)^3-(x-1)^3][(x+1)^3+(x-1)^3]-1344x=0$$
$$(x^3+3x^2+3x+1-x^3+3x^2-3x+1)(x^3+3x^2+3x+1+x^3-3x^2+3x-1)-1344x=0$$
$$(6x^2+2)(2x^2+6x)-1344x=0$$
$$4x(3x^2+1)(x^2+3)-1344x=0$$
$$(3x^2+1)(x^2+3)-336=0$$
$$3x^4+10x^2-333=0$$
$$x^2=\frac{-10\pm\sqrt{100+3996}}{6}$$
$$x^2=\frac{-10\pm 64}{6}$$
$$x^2=9$$
$$x=+3 \text{ and } -3$$
$$x^2=\frac{-37}{3}$$
$$x=\frac{+i\sqrt{111}}{3} \text{ and } x=\frac{-i\sqrt{111}}{3}$$
$$4x=0$$
$$x=0$$

The equation is really of the fifth degree as seen in the expanded form. Therefore there are only five roots.

Solutions were also offered by J. Byers King, Denton, Md.; Horace Mourer, Belleville, Mich.; W. R. Talbot, Jefferson City, Mo.; C. W. Trigg, Los Angeles, Calif.; Dale Woods, Pocatello, Idaho; and the proposer.

STUDENT HONOR ROLL

The Editor will be very happy to make special mention of classes, clubs, or individual students who offer solutions to problems submitted in this department. Teachers are urged to report to the Editor such solutions.

Editor's Note: For a time each student contributor will receive a copy of the magazine in which his name appears.

For this issue the Honor Roll appears below.

2672. 2674. 2676. *Lee H. Mitchell, Glencoe, Ill.*

2672. 2676. *Tom Apelquist, Dyer, Ind.*

2676. *Ray Ward, Indianapolis, Ind.*

2676. *Robert Milburn, Indianapolis, Ind.*

2676. *Garry Boyd, Gilbert Burm, Susan Flotte, Louis Hancotte, Bill Jones, Robert Miller, David Panzer, Charles Shoemaker, Van Buren High School, Belleville, Mich.*

2676. *John F. Osinski, State Teachers College, Salisbury, Md.*

PROBLEMS FOR SOLUTION

2695. *Proposed by Leo Moser, University of Alberta.*

Four brothers now living were born on 4 different years of the same decade. The four years of birth involved are all prime numbers. How old are they now?

2696. *Proposed by Cecil B. Read, Wichita, Kans.*

Show that

$$1/(1\cdot2\cdot3)+1/(3\cdot4\cdot5)+1/(5\cdot6\cdot7)+\cdots+1/(2n-1)(2n)(2n+1)+\cdots$$

is equal to Ln $2-\frac{1}{2}$/

2697. *Proposed by Bjarne Skaug, Oslo, Norway.*

Between two intersecting straight lines m and 1 is given one point P. Find an equilateral triangle having one vertex at P and one on each of the straight lines.

2698. *Proposed by John Satterly, University of Toronto.*

The bisectors of angles A, B, and C of triangle ABC cut the opposite sides at D, E, and F respectively. They also intersect one another at the incenter I. Draw DE cutting CF in x. Show that

a) $Cx/CI=(a+b+c)/(a+b+2c)$
b) $Cx/xF=(a+b)/2c$.

2699. *Proposed by Brother T. Brendan, St. Mary's College, California.*

In an article by Prof. Buck in the March 1959 *American Mathematical Monthly*, pp. 207, we find mention of the following problem given to eighth-graders in the national competition of 1956 in the USSR: "Through two given points on the circumference of a circle draw two parallel chords having a specified sum." Find such a construction for those cases where the given conditions permit it.

2700. *Proposed by J. B. Flansburg, Houston, Texas.*

Prove that there is no n for which the value of

$$\frac{1}{2}+1/3+1/4+\cdots+1/n$$

is integral.

Books and Teaching Aids Received

THE EARTH AND ITS RESOURCES, by Vernor C. Finch, *University of Wisconsin*, Glen T. Trewartha, *University of Wisconsin*, and M. H. Shearer, *Westport High School*. Cloth. Pages viii+584. 16.5×23.5 cm. 1949. McGraw-Hill Book Company, Inc., 330 West 42nd Street, New York 36, N. Y. Price $6.00.

FUNDAMENTALS OF FRESHMAN MATHEMATICS, by C. B. Allendoerfer, *University of Washington*, and C. O. Oakley, *Haverford College*. Cloth. Pages vii+475. 15×23 cm. 1959. McGraw-Hill Book Company, Inc., 330 West 42nd Street, New York 36, N. Y. Price $6.50.

DICTIONARY OF EDUCATION, Carter V. Good (Editor), *University of Cincinnati*. Cloth. Pages xxvii+676. 15×23 cm. 1959. McGraw-Hill Book Company, Inc., 330 West 42nd Street, New York 36, N. Y. Price $9.75.

BRAZIL, EDUCATION IN AN EXPANDING ECONOMY, by Augustus F. Faust, *University of Utah*. Paper. Pages ix+142. 14.5×23 cm. 1959. U. S. Department of Health, Education, and Welfare, Washington, D.C. Price $.50

INTERMEDIATE ALGEBRA FOR THE COLLEGE STUDENT, by J. Vincent Robison, *Oklahoma State University*. Cloth. Pages vii+286. 15×23 cm. 1959. D. Van Nostrand Company, Inc., 120 Alexander St., Princeton, New Jersey. Price $4.25.

MATHEMATICS AND THE PHYSICAL WORLD, by Morris Kline. Cloth. Pages ix+482. 15×22.5 cm. 1959. Thomas Y. Crowell Company, 432 Fourth Avenue, New York 16, N. Y. Price $6.00.

INTRODUCTION TO THE LAPLACE TRANSFORM, by Dio L. Holl, Clair G. Maple, and Bernard Vinograde, *Iowa State College*. Cloth. Pages viii+174. 14×21.5 cm. 1959. Appleton-Century-Crofts, Inc., 35 West 32nd Street, New York 1, N. Y. Price $4.25.

DEVELOPMENT AND STRUCTURE OF THE FROG, A PHOTOGRAPHIC STUDY, by Addison E. Lee, *University of Texas*, Earl R. Savage, *Richmond Public Schools*, and W. L. Evans, *University of Arkansas*. Paper. Pages iv+44. 18.5×25 cm. 1959. Rinehart & Company, Inc., 232 Madison Ave., New York 16, N. Y. Price $1.00.

A GUIDED TOUR THROUGH SPACE AND TIME, by Eva Fenyo. Cloth. Pages x+181. 13.5×20.5 cm. 1959. Prentice-Hall, Inc., Englewood Cliffs, N. J. Price $3.50.

THE ROCKET HANDBOOK FOR AMATEURS, Lt. Col. Charles M. Parkin, Jr. (Editor). Cloth. Pages—306. 14×21.5 cm. 1959. The John Day Company, Inc., 62 West 45th Street, New York 36, N. Y. Price $5.95.

ON MATHEMATICS AND MATHEMATICIANS, by Robert Edouard Moritz. Paper. Pages vii+410. 13.5×20.5 cm. 1914, 1942. Dover Publications, Inc., 920 Broadway, New York 10, N. Y. Price $1.95.

OUR SPACE AGE JETS, by C. B. Colby. Cloth. 48 Pages. 17.5×26.5 cm. 1959. Coward-McCann, Inc., 210 Madison Ave., New York City. Price $2.00.

PLASTIC MAGIC, THE MATERIAL OF A MILLION USES, by C. B. Colby. Cloth. 48 Pages. 17.5×26.5 cm. 1959. Coward-McCann, Inc., 210 Madison Ave., New York City. Rice $2.00.

SNOW SURVEYORS, DEFENDERS AGAINST FLOOD AND DROUGHT, by C. B. Colby. Cloth. 48 Pages. 17.5×26.5 cm. 1959. Coward-McCann, Inc., 210 Madison Ave., New York City. Price $2.00.

MAPPING THE WORLD, by C. B. Colby. Cloth. 48 Pages. 17.5×26.5 cm. 1959. Coward-McCann, Inc., 210 Madison Ave., New York City. Price $2.00.

ELEMENTARY DECISION THEORY, by Herman Chernoff and Lincoln E. Moses. Cloth. Pages xv+365. 15×23 cm. 1959. John Wiley & Sons, Inc., 440 Fourth Ave., New York 16. N. Y. Price $7.50.

THE SPANISH PLATEAU, by Peter Buckley. 96 Pages. 13.5×21 cm. 1959. Coward-McCann, Inc., 210 Madison Ave., New York City. Price $2.50.

MEN, MOSS AND REINDEER, by Erick Berry. 96 Pages. 13.5×21 cm. 1959. Coward-McCann, Inc., 210 Madison Ave., New York City. Price $2.50.

PHYSICS, AN EXACT SCIENCE, by Harvey E. White, *University of California*. Cloth. Pages xi+597. 17×24 cm. 1959. D. Van Nostrand Company, Inc., 120 Alexander Street, Princeton, New Jersey. Price $5.96.

A TABLE OF THE INCOMPLETE ELLIPTIC INTEGRAL OF THE THIRD KIND, by R. G. Selfridge and J. E. Maxfield, *Research Department, U. S. Naval Ordnance Test Station*. Cloth. Pages xiv+805. 14×21.5 cm. 1958. Dover Publications, Inc., 180 Varick Street, New York 14, N. Y. Price $7.50.

AN INTRODUCTION TO MATHEMATICS, by Donald W. Western and Vincent H. Haag, *Franklin and Marshall College*. Cloth. Pages xi+580. 16.5×23.5 cm. 1959. Henry Holt and Company, 383 Madison Avenue, New York 17, N. Y. Price $7.50.

SCIENTIFIC THOUGHT, by C. D. Broad. Paper. 555 Pages. 12.5×20.5 cm. 1959. Littlefield, Adams & Company, Paterson, New Jersey. Price $1.95.

PRINCIPLES OF TRANSISTOR CIRCUITS, by S. W. Amos, *Engineering Training Department, British Broadcasting Corporation.* Paper. Pages viii+167. 14×21.5 cm. 1959. John F. Rider Publisher, Inc., 116 West 14th Street, New York 11, N. Y. Price $3.90.

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THE LIFE OF SIR ALEXANDER FLEMING, DISCOVERER OF PENICILLIN, by André Maurois, Translated by Gerard Hopkins. Cloth. 293 Pages. 14.5×21.5 cm. 1959. E. P. Dutton & Company, 300 Fourth Ave., New York 10, N. Y. Price $5.00.

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THE RAND MCNALLY HANDBOOK OF MAP AND GLOBE USAGE, by Ruby M. Harris. Paper. Pages vi+392. 15.5×23 cm. 1959. Rand McNally & Company, P. O. Box 7600, Chicago 80, Illinois .

PROPOSED CHANGES IN CASMT BY-LAWS

The following changes have been proposed for the By-Laws and will be voted on at the annual meeting in November.

Present	*Proposed*
Article I, Section I QUALIFICATIONS: Any teacher or other person, firm, or corporation, interested in any aspect of the teaching of science or mathematics shall be eligible for membership in this Association.	QUALIFICATIONS: Any teacher or other person interested in any aspect of teaching, etc.
Article I, Section II ELECTION: Every applicant for membership, unless otherwise provided by the Board of Directors, shall present a written application therefor, accepting and agreeing to abide by the provisions of these By-Laws and amendments thereto, which application shall be submitted to the Secretary, or any officer of this Association, and referred by him to the Committee on Membership for its approval or disapproval. The application, together with recommendations of the Committee on Membership, shall be submitted to and acted upon by the members of the Board of Directors. A two-thirds vote of the members present at any regular meeting of the Board of Directors shall be sufficient to elect to membership.	ELECTION: A qualified person becomes a member upon submitting a completed application blank and payment of dues.
Article I, Section III TERMINATION OF MEMBERSHIP: The membership of any member of the Association shall be automatically terminated for any delinquency of dues, or other charges owing to the Association, continued for a period of six months. Any member of the Association, etc.	TERMINATION OF MEMBERSHIP: membership of any member of the Association shall be automatically terminated for any delinquency of dues, or other charges owing to the Association. During the first six months of such delinquency the person may upon request and payment of back dues be restored to membership without losing continuity of membership. Any member of the, etc.
Article V, Section V: PROGRAM COMMITTEE: The Chairman, Vice-Chairman, and Secretary of each of the sections provided for in the next preceding paragraph, together with the Officers of the Association, shall constitute a Program Committee. The Program Committee shall prepare and have charge of the program of the annual meeting of the Association.	PROGRAM COMMITTEE: The program committee shall consist of the chairmen of all sections, the Vice-President, and other such members as the President may appoint. The Vice-President shall act as chairman of this committee. The program committee shall prepare and have charge, etc.

Book Reviews

OUR EARTH, by Arthur Beiser. Cloth. 123 pages. 13×20 cm. 1959. E. P. Dutton and Co., 300 4th Avenue, New York 10, N. Y. Price $2.95.

The author of *Our Earth* has attempted within 123 pages to supply the latest information about the size of the earth, its position in the solar system, its composition and surface, the effects of the atmosphere and the tides and terrestrial magnetism. In the concluding sections, he discusses the most recent evidence about the age of the earth and why possibly in the far distant future the sun will expand to the size of the orbit of Venus and wipe out all life on the earth. This is indeed a large order. The author has already written other semi-technical books such as *Physics for Everybody* and *Guide to the Microscope.*

The presentation of the topics jumps from mountain top to mountain top without treading the valleys. In general, it consists of the more startling facts about the topics just mentioned. It is doubtful, however, whether the unsophisticated novice would have the background to fill in the gaps. The sophisticated scientists would find little new information.

There is little question that a science teacher having little background in earth science would find the book of great value for filling in his information in this area. The book would be interesting to him. The intelligent layman with an urge to become more acquainted with earth science would also find the reading an interesting chore.

The reviewer somewhat questions the teleological and anthropomorphic approaches to topics that appear from time to time. For example, "The [earth's] crust has a poor memory, and delights in obscuring its past by smoothing down the rough places and filling in the hollows; but it cannot suppress the rumblings indicative of inner turmoil . . . " (p. 53).

There are several places where statements can be questioned, for example:

"The real *pièce de résistance* of fossil magnetism is the discovery that the earth's magnetic field has reversed itself innumerable times" (p. 91).

It is pointed out later that "not all of the evidence pointing to this fact can be accepted as legitimate." Whether or not points should be phrased in this way with such later qualification is dubious.

Despite its shortcomings, the book is interesting and "makes good reading."

G. G. M.

THE MACMILLAN SCIENCE/LIFE SERIES, BOOKS 1–6:

Book 1, by J. Darrell Barnard, Celia Stendler, Benjamin Spock, and Mary W. Moffit, Pp. 122, Price $2.32;

Book 2, by J. Darrell Barnard, Celia Stendler, Benjamin Spock, and Mary W. Moffit, Pp. 154, Price $2.48;

Book 3, by J. Darrell Barnard, Celia Stendler, Benjamin Spock, and George Reynolds, Pp. 250, Price $2.72;

Book 4, by J. Darrell Barnard, Celia Stendler, Benjamin Spock, Eleanor Delaney, and George Reynolds, Pp. ix+262+xxvi, Price $2.80;

Book 5, by J. Darrell Barnard, Celia Stendler, Benjamin Spock, and J. Myron Atkin, Pp. ix+310+xxvi, Price $2.88;

Book 6, by J. Darrell Barnard, Celia Stendler, Benjamin Spock, Margaret Braidford, and J. Myron Atkin, Pp. ix+310+xxvi, Price $2.96.

All books in series: cloth. 19×23.5 cm. 1959. Macmillan Co., 60 5th Avenue, New York 11, N. Y.

Within the past few years a number of excellent series of textbooks for elementary science have appeared on the market. Even a cursory examination will indicate that most of them are vast improvements over similar textbooks published as little as ten years ago. Thus, a new series must face stiffer competition and must have higher quality than ever before, if it is to have impact. When a new series appears, therefore, it must be evaluated by two criteria:

1. Does it do better what the other series already do?
2. Is it sufficiently different from the other series so that new approaches and

patterns for teaching elementary science are possible?

In answering these questions, one must recognize that this series differs markedly from the other series on the market. The advertising literature as well as the Teachers Annotated Edition state clearly that the series is a unified program involving the biological and physical sciences, the science of behavior (with emphasis on human adjustment), and health and safety.

As is common with science series, the emphasis in the textbooks for the earlier grades is on the biological sciences, with an increased emphasis on the physical sciences in the later grades. In general, the traditional areas of science are covered and need not be listed here. However, among them are found units and sections entitled "Getting Along With Others," (p. 240, Book 3); "Building Friendships," (p. 140, Book 3); "Helping Yourself," (p. 154, Book 6); and "Your Feelings," (p. 107, Book 5). The latter reference is part of "Developing Your Own Personality." Integrated throughout the science subject matter are related discussions involving health and safety.

The reviewer read the series carefully and then compared it with several of the more recent series. He has the following impressions:

1. The book is well written. The materials are well presented, understandable, and seem to be accurate.
2. As compared with an equivalent number of pages from other series, there is a reduction of the content of traditional scientific material. This would obviously be necessary when material from other areas (health, safety, human adjustment) are included.
3. The Teacher's Annotated Editions are among the best that the reviewer has ever seen. The introductory pages are well written and describe the philosophy of the series clearly. The suggestions and comments printed directly on the pages in red ink make it unnecessary for the teacher to jump about from the book page to the suggestions printed elsewhere.
4. There is a great deal of emphasis on pupil activity and scientific thinking throughout the various books. This, in the opinion of the reviewer, is highly salutary.

In answering the questions in the criteria, the reviewer believes the following to be a reasonable summary:

1. This series does *not* do better what the other series already do. It is not a page-by-page logically-developed presentation of scientific information. Nor, does it cover quite so extensively the traditional science areas.
2. The series is different from the others in that it does an excellent job integrating science with health, safety, and human adjustment. It does, in so far as comparing it with other series will indicate, offer opportunity for different approaches and patterns for teaching elementary science.

It will be liked by those who favor integration of these areas. It will not be popular with those who prefer a more independent approach to science.

G. G. M.

THE MAMMALS OF NORTH AMERICA, Volumes I and II, by E. Raymond Hall, *Summerfield Distinguished Professor, Chairman of the Department of Zoology*, and *Directory of the Museum of Natural History, University of Kansas*, and Keith R. Kelson, *Division of Scientific Personnel and Education, National Science Foundation*. Cloth. Pages xxxviii+1083. 20×27 cm. 1959. The Ronald Press Company, 15 East 26th Street, New York 10, New York. Price $35.00—2 vol. set.

Nearly every publisher likes to think of every one of his books as being monumental. In most cases, the books fail to approach this criterion. However, in the case of *The Mammals of North America, Volumes I and II*, the reviewer believes that the adjective fits. It would be impossible, of course, for any one reviewer to check on the accuracy of such a vast work. Few have the background, time, or facilities. However, the distinguished authorship as indicated in the citation is ample evidence to the reviewer that quality is most likely, if not assured.

During the period of five months in which the reviewer has had possession of the books, he has allowed several colleagues whose specialties are in mammology

to examine them and use them. He has himself examined them and used them on several occasions. Without exception, they provided the information that was deliberately sought on a random basis or else needed for special purposes. Without doubt they are complete both in inclusions of species and in the listing of their known characteristics.

One must realize that these volumes are not textbooks nor are they designed for weekend reading. They are encyclopaedic documents covering the members of the Class Mammalia in the geographical area indicated. The various orders are treated from the lowest Marsupialia through Insectivora, Chiroptera, Primates, Edentata, Lagomorpha, Rodentia, Cetacea, Carnivora, Pinnipedia, Sirenia, Perissodactyla to Artiodactyla.

The taxonomic limits assigned to any category, according to the authors, reflects their own personal judgment. In general, however, they indicated that they "have accepted the last-published opinion that was supported by evidence obtained by examination of specimens." "Where the literature contained conflicting statements and obviously improbable identifications," the authors with in the time and opportunities available obtained specimens, studied them, and published the findings.

In choosing zoological names, the 10th edition of *Systema Naturae*, 1758, by Linnaeus "was taken as the starting point." The law of priority was then used to stabilize the nomenclature.

Within this design, the authors attempted "to include all pertinent taxonomic and distributional information . . . [available through] October 31, 1957."

Each species (or sub-species) as it appears in the compendium is listed with external measurements, outstanding markings, facts concerning distribution, and marginal records, together with skeletal information, mating seasons and other information where pertinent. Sources of the descriptive material are documented for each.

The general impression of the reviewer is that the document is absolutely essential for every college and university that offers a biology course. It is doubtful whether any instructor, undergraduate major, or graduate student in biology could "get along" without using it at one time or another. It is obvious that this book is not going to be superceded by new editions every three years or become obsolete in 10 years. This is an almost timeless publication.

Whether the publishers are correct in stating that it "will take its place with the books of Linnaeus (1758) and Spencer (1858) on the same subject," only time will tell. The reviewer is inclined to support them.

G. G. M.

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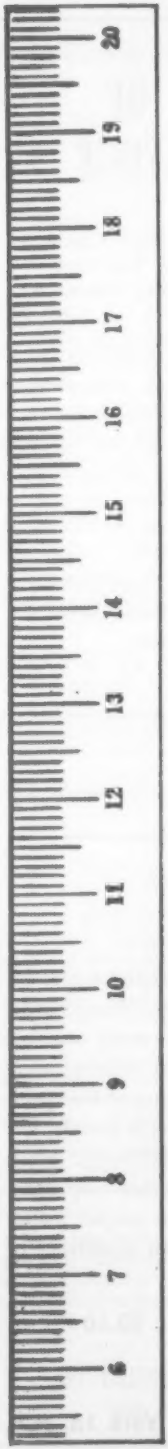

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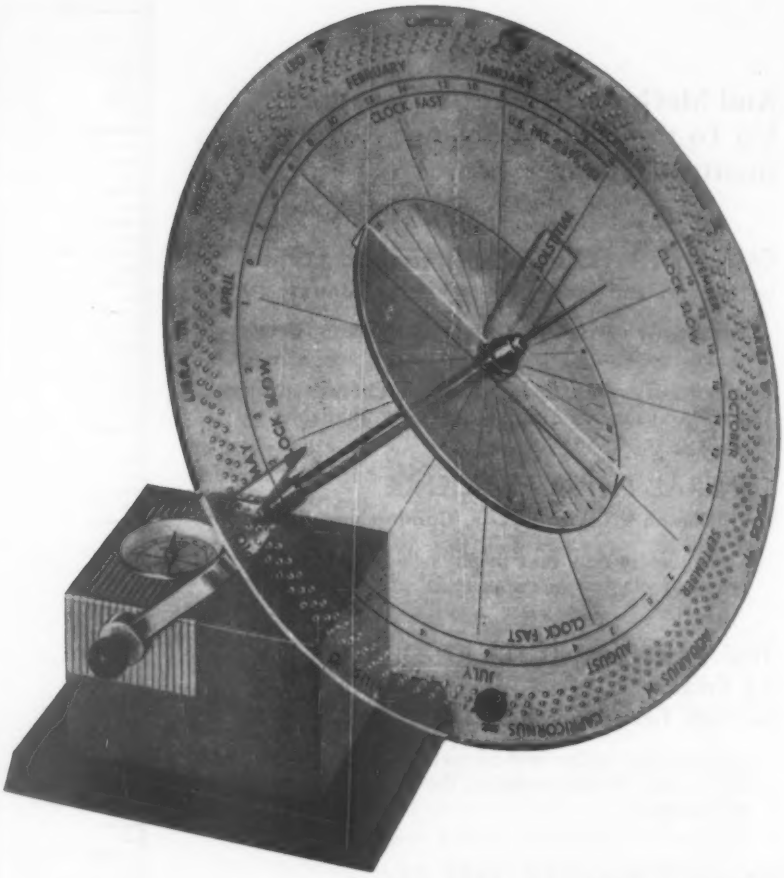

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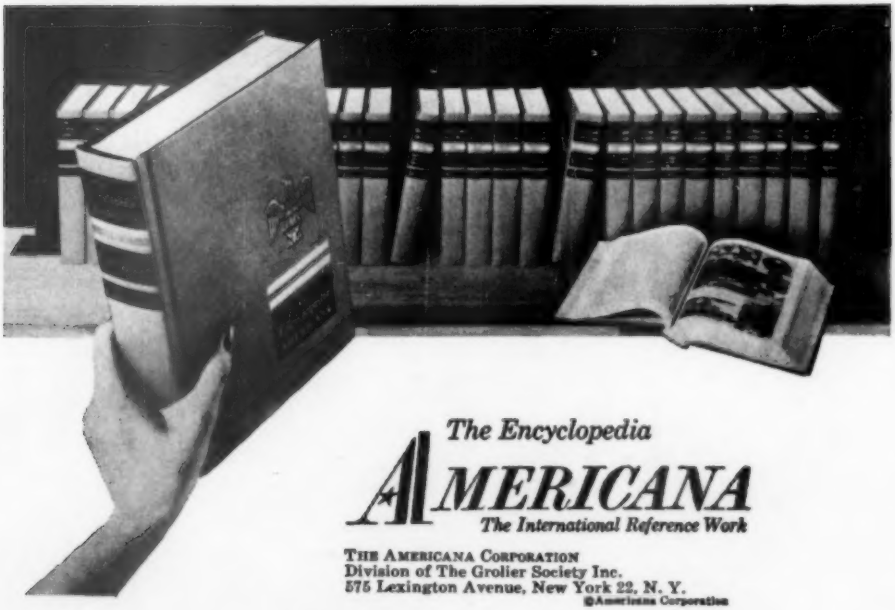

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